

FINAL REPORT

STUDY OF MARKETS FOR
POST CONSUMER PLASTICS

FOR

NORTHEAST RECYCLING COUNCIL

APRIL, 1992

R.W. BECK
AND ASSOCIATES



printed on recycled paper

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Printed in the United States of America

△ The Council of State Governments
Iron Works Pike • P.O. Box 11910
Lexington, KY 40578-1910

C-035-92

Price \$25.00

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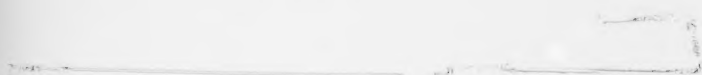


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Executive Summary

This Report examines the market for seven post-consumer plastic resins ("PCR") which accounted for 72 percent of total 1990 U.S. plastics sales. These resins are:

- o Polyvinyl Chloride ("PVC")
- o Polypropylene ("PP")
- o High Density Polyethylene ("HDPE")
- o Low Density Polyethylene ("LDPE")
- o Linear Low Density Polyethylene ("LLDPE")
- o Polystyrene ("PS")
- o Polyethylene Terephthalate (PET)

The Report is divided into four parts.

Part 1

The first part examines the generation and supply of these resins based on 1990 plastics sales figures. The types of post-consumer products which are most likely to be recovered are non-durable products such as packaging and disposables. The seven resins accounted for about 99 percent of these types of products. The 1990 total U.S. sales and per capita sales of non-durable consumer products for the seven resins were:

<u>Resin</u>	<u>1990 Total Sales</u>	<u>Per Capita Sales</u>
PVC	743 million lbs	3.0 lbs
PP	1,083 million lbs	4.3 lbs
HDPE	3,770 million lbs	15.1 lbs
LDPE	1,889 million lbs	7.6 lbs
LLDPE	1,801 million lbs	7.2 lbs
PS	2,196 million lbs	8.8 lbs
PET	1,759 million lbs	7.0 lbs
TOTAL	13,241 million lbs	53.1 lbs

Executive Summary

The Report also presents the product types and fabrication technologies for each of the seven resins. The three resins which make up the largest percentage of non-durable consumer products are HDPE, LDPE, and PS. Plastic film, made from HDPE, LDPE, and LLDPE was, by far, the most common type of product, accounting for almost 8 percent of all plastic sold in the United States.

The Report examined the seasonality of plastic disposal and did not find strong evidence of seasonal variation in the disposal of plastic scrap.

Collection studies from Highland Park, New Jersey, and Minneapolis, Minnesota were analyzed to estimate the amount of plastic collected in curbside programs targeting plastics. The results of these studies show that less than 25 percent of non-durable products are collected in curbside programs that collect plastics. The resins/products with the highest collection rate were HDPE milk and water jugs and PET soda bottles.

Section 1 - Conclusions

1. The seven resins which are the focus of this Report accounted for 72 percent of total U.S. sales of plastics in 1990.
2. These seven resins also accounted for about 99 percent of the non-durable consumer products manufactured; about 45 percent of the durable consumer products; and 64 percent of the commercial/industrial products.
3. The three individual resins most commonly found in non-durable consumer products are HDPE, LDPE, and PS.
4. By far, the plastic application accounting for the largest fraction of the plastic waste stream is film. Other easily identifiable plastic products which are plentiful in the waste stream are PET soft drink bottles, HDPE bottles for household chemicals, and HDPE milk jugs.

<u>Product</u>	<u>1990 Sales (millions of lbs)</u>	<u>Percent of 1990 Sales</u>
Plastic Film	4,908	7.98
PET soft drink bottles	754	1.23
HDPE household chemical bottles	926	1.51
HDPE milk/water jugs	736	1.20

5. Because HDPE, LDPE and LLDPE film are similar in appearance, residents and businesses will have difficulty distinguishing among them.

Section 1 - Recommendations

1. Based on the amounts of HDPE used for milk and water jugs and the amounts of PET used for soft drink bottles, residential recycling programs should continue to collect these products.
2. Film recycling holds promise as a means of substantially reducing the commercial and institutional plastic waste stream.
3. Because PP and PVC are relatively small fractions of the residential waste stream, these two resins should not be targeted for collection unless an efficient and cost-effective sorting technology can be developed.

Opportunities may exist for recovering PP and PVC in durable products or from commercial/industrial sources.
4. Although the amount of PS sold to consumers and disposed of by residents suggests that this resin could be targeted for recycling, difficulties with collection and contamination make it expensive to recover from the residential waste stream. A more cost-effective approach is to identify specific commercial and institutional locations, such as schools, fast-food restaurants, and institutions, such as schools, which generate large amounts of relatively clean

Executive Summary

PS that could be targeted for recycling programs. This approach is already being used in many schools and other locations in the Northeast.

Part 2

The second part of the Report addresses the recoverability of these residential resins and products. Eleven factors which affect the recovery of post-consumer plastics are identified and discussed. These factors are

- o Quantity available
- o Ease of identification
- o Cross contamination
- o Content contamination
- o Processing capacity
- o Resin production and price cycles
- o Reclaiming markets
- o Market price of virgin/off-spec/recycled resins
- o Value added product applications
- o Consumer environmental concern
- o Legislation

Many interrelationships exist among these factors with the most common denominator being recovery economics. The three resins/products with the highest recovery rates in 1990 were:

<u>Resin Product</u>	<u>Amount Sold⁽¹⁾</u>	<u>Amount Recovered⁽¹⁾</u>	<u>Percent Recovered</u>
PET Soda Bottles	754	224.65	29.8
PP Battery Casings	156	135.35	88.7
HDPE Milk/ water jugs	1,076	57.51	5.3

⁽¹⁾ millions of pounds

Section 2 - Conclusions

In terms of recovery, postconsumer resins/products can be divided into three groups.

- (1) Resins/products which are being successfully recovered at the present time, include PET soft drink bottles, HDPE milk and water jugs, HDPE pigmented consumer bottles which have not contained chemicals, PP battery casings, and HDPE soft-drink base cups.
- (2) Resins/products which have good potential to be recovered in the future, but must overcome relatively minor barriers to recovery, including custom PET bottles (for Spic and Span and Gatorade), PET x-ray film, HDPE household chemical bottles, HDPE and LDPE/LLDPE film bags.
- (3) Those resins/products which currently face significant barriers to recovery, including PS packaging from residential generators, PVC bottles, and PP bottles. These barriers may be overcome by public/handler education and commercialization of automated sorting technology.

There are a number of resins/products which might be targeted for recovery from institutional/commercial/industrial generators, including PET x-ray film HDPE stretch and shrink wrap, agricultural film, HDPE crates, drums, pallets, and pails, PVC pipe and conduit, PVC siding, and PS food service products.

Section 2 - Recommendations

The following recommendations should lead to increased recovery of a broader range of plastics over a longer time period. Additionally, if pursued, these recommendations should improve existing recovery programs.

- Mixed residential film recycling has potential for recovery but should not be pushed forward too rapidly. Rather, observation of the progress in facilities such as Rhino-X, Petoskey

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Plastics, Inc., Southeastern Recycling, and North American Plastics should precede the implementation of large-scale programs. Alternatively, film should be targeted for commercial and industrial recovery.

- An education program for reclaimers of silver from X-ray film is recommended, to raise awareness about the recyclability of PET film. Perhaps a match program of PET reclaimers with silver reclaimers could also be undertaken, to make sure the PET material has an outlet prior to the silver reclaimer making changes in solutions.
- Because of stable markets, valuable end products, and a well-developed infrastructure, PET bottles should be targeted for recovery, although focus should be placed on designing PET non-soft drink bottles for recycling and public education stressing bottle rinsing and drainage.
- Processors of PET and HDPE could cooperate with the PVC industry to sort and make available for shipment PVC bottles from mixed streams.
- Product definition (i.e., the designation of containers by product type, brand name, or shape, such as soft drink or narrow neck bottles) should be used to enhance public education. Number codes should only be used if markets are secured for the wide range of materials generated by using the number codes such as custom PET bottles or injection grade HDPE.
- Proper drainage of bottles should also be emphasized in public education, particularly with regard to bottles containing hazardous waste.
- A modest training program to help full-time sorters in plastic sorting facilities identify containers such as PET look-alikes (e.g., PVC Wesson Oil bottles) could improve recovery of the plastic bottle stream.
- EPA should take the lead in re-examining the recommendation for proper disposal of home use medical waste in light of contamination of recyclables, especially those generated in mixed waste processing facilities.

- To balance virgin resin production and price cycles, industry could consider the development of recycling capacity on the front end of petrochemical plant expansions.
- Reduction of cross-contamination through recyclability campaigns, technical assistance, or legislation should be pursued.
- The public procurement of recycled plastic products would greatly improve the absorption of postconsumer products. Mandated public procurement of recycled plastic products at the local, state, and federal levels of government should be strongly supported.

Part 3

The third part of the Report covers the economics of sorting because sorting into recycling-compatible streams is a critical issue in the recovery of post-consumer plastics. This part of the Report examines both collection and centralized processing. The relative cost of processing post-consumer plastic is shown below:

<u>Process</u>	<u>Cost in \$/lb</u>
Collection	\$0.046
Sorting	\$0.02 - \$0.04
Baling/Granulating	\$0.015/\$0.05
Transportation	\$0.02
Cleaning	\$0.10
Pelletizing	\$0.06
TOTAL	\$0.0261 - \$0.316

Because sorting may take place at the point of collection, three types of collection are discussed: curbside collection, drop-off centers, and buyback centers. Based on a national survey, drop-off centers are the most common type of collection program, followed by curbside collection, and buyback centers. Many communities employ more than one type of collection system. Because plastics are light and voluminous, collection/

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transportation costs are high. Collection programs which can densify plastic economically can reduce these costs. Compaction units on collection trucks are effective way to do this. Choosing between commingled collection and source-separated collection involves weighing ease of collection against ease of processing. The cost of sorting at the processing facility will be a critical factor. If sorting at the processing facility is low, commingled collection will make more sense; if it is high, source-separated collection may be advisable. Because communities allocate and calculate collection costs differently, it is difficult to compare costs. One study showed plastics collection costs for 18 programs across the U.S. ranged from \$0.02/lb to \$0.10/lb. The average cost for three collection programs in the northeast was \$0.07/lb.

Although participation and capture rates for drop-off programs are often below those of curbside programs, drop-off centers can achieve comparable rates if they are supported with comparable education and staffing.

A variety of streams of plastic can be sorted for at a central facility depending on a number of factors. Manual sorting is the most widely used method at the present time, with sorting rates ranging from less than 100 lbs/hr to more than 500 lbs/hr depending on the incoming plastic stream and the number of sorts required. With high sorting rates, costs of approximately \$0.02/lb. can be achieved. Mechanical sorting is still in its infancy with a number of experimental technologies now being developed. These technologies include macrosorting for whole bottles, using photoelectric sensors and x-rays, or microsorting, for granulated plastic, using flotation.

Section 3 - Conclusions

- On-board plastic compactors are efficient, economical, and compatible with most collection and processing systems.
- Drop-off programs for all plastics are useful in rural areas and in supermarkets for film plastic collection.
- Bottle deposit legislation may help spur the collection of certain plastic items in a clean, homogeneous stream. Such legislation may also undermine the collection of other plastic

products at the expense of other plastic products or collection methods. (PET soft drink bottles collected in such programs leave little revenue-producing plastics to help support curbside programs.) At the same time, deposit legislation has led to the recovery of large amounts of PET soft drink bottles and has been responsible for creating the bottle recycling infrastructure in those states with deposit legislation.

- Mixed waste processing facilities may or may not, in the future, be responsible for the collection of much greater levels of plastics for recycling. However, high levels of contamination of certain items, such as plastic film, have characterized these facilities.

Current centralized sorting techniques are almost exclusively performed with the use of manual labor. It is unlikely that extensive automated sorting will become commercially available for at least the next 12-18 months.

Until such time, improving the cost effectiveness of hand sorting will rely upon the development of clear educational literature for collection program participants emphasizing the product types or physical characteristics of the bottles to reduce contamination levels before reaching the plastic handler's facility. Moreover, eliminating certain unnecessary handling procedures such as baling and debaling and improved sorting and the addition of the grinding activity at the MRF/plastic handling facility (subject to reclaimer acceptance of ground material) could not only improve the net profit margin of these facilities, but could also reduce the cost associated with the transportation of waste materials invariably found in mixed bales.

Section 3 - Recommendations

- Curbside collection of residential postconsumer plastics should be chosen by any municipality capable of supporting such a program.
- Commingled collection may or may not be more economical than separated collection depending on the presence of a MRF,

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applicable MRF charges and the existence of other recycling infrastructure.

- Drop-off (as well as other) collection programs must include appropriate signage (minimal verbiage, pictures of accepted products) and be staffed at certain times, in order to minimize contamination problems. It may be of value to repeat this procedure on a regular basis for new participants or if material quality begins to deteriorate.
- Drop-off (as well as other) collection programs for multi-family residences must include continuous education of new tenants.
- Encourage and/or assist in the development of carefully designed educational literature to increase public understanding of which plastic products are currently recyclable. The literature should focus on specific types of product for recovery (milk, soft drink, laundry, plastic bags) and/or physical characteristics of the materials to be collected that are easily recognizable (e.g., narrow neck bottles). The literature should also stress the removal of caps, rinsing, and stepping the plastic bottles for volume reduction before collection.
- Develop educational literature on a technical operator's program to educate MRF and other plastic handling facility operators and ultimately their sorting line crew as to the appropriate plastics to be collected and methods for most effectively hand-sorting plastic [i.e., remove dominant resins first (PET soft drink, HDPE milk) followed by HDPE laundry (light/dark cut sort), clear bottles into PET and PVC, etc.)]
- Attempt to establish grinding operations at the handling facility in order to improve the MRF's or other plastic handling facility's net income stream from plastic. It will be extremely important to establish a close working relationship with one or more plastic reclaimers willing to accept the ground material prior to implementation.
- Continue to monitor the commercialization of automated sorting technology. The advent of such technology will likely dictate the future course of residential postconsumer plastic bottle recovery efforts.

Part 4

The fourth part of the Report looks at potential end-use markets for PCR. The market is divided into three product categories, based on the resin specification. The first category includes a limited number of products with broad resin specifications, such as plastic lumber and curbside recycling containers. These products use large amounts of PCR, but the market for these products is limited. Developing new products and enlarging the markets for the existing products would stimulate the market for PCR.

The second category is made up of products such as soda bottles, non-food bottles, and construction materials, which have narrow resin specifications. Regulatory or technical barriers restrict the amount of PCR which can be used in these products. For example, the Federal Food and Drug Administration has recently allowed the use of PCR in soda bottles. This may open the way for closed-loop recycling of PET soda bottles.

Products in the third category have very narrow resin specifications and are not likely to contain PCR for the foreseeable future. These products include medical products with high performance characteristics and which cannot risk potential contamination from PCR. This category also includes automotive products where color matching is critical and where performance standards are also high. The variability and potential contamination of PCR makes it unsuitable for these products

Section 4 - Conclusions

1. The following are barriers to the use of recycled plastic in products with broad resin specifications.
 - There are a limited number of products with broad resin specifications.

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- Durable products, such as plastic lumber and recycling containers, will not provide a closed-loop end-use for plastic recovered from non-durables such as packaging.
 - Markets for many products with broad resin specifications, such as plastic lumber and flower pots, are limited.
2. Opportunities for recycled products with narrow resin specifications have been growing as improvements in the supply of PCR, technologies, and markets occur.
 3. The following are barriers to the use of recycled plastic in products with narrow resin specifications:
 - Regulations regarding direct food containers,
 - Technical limits to recycled content,
 - Supply and quality of collected scrap,
 - Consumer perceptions of plastic recyclability,
 - Manufacturers concern about the use of recycled resins.
 4. Manufacturers of products with very narrow resin specifications are not likely to incorporate PCR into their products for the following reasons:
 - Many products use resins which are not found in large amounts in the residential waste stream, such as PP and PVC.
 - PCR does not meet the resin specifications standards of these manufacturers and current technology is not capable of consistently bringing the quality of the PCR to these standards.

Section 4 - Recommendations

1. Because post-consumer resin ("PCR") will compete with both virgin resin and commercial/industrial scrap, the importance of developing a clean, well-sorted supply of PCR is critical to the success of recycling.

- NERC should encourage manufacturers to "design for recyclability" by urging the use of identical, or at least recycling-compatible, resins in product types.
- 2. NERC could encourage the purchase of recycled plastic products by individual consumers and government entities.
- 3. NERC should encourage performance-based standards for government procurement policies. The public will not be served by encouraging lower standards for recycled products.

For the long-term, recycled products should compete equally with products made with virgin resin. A graduated price preference for some products for two or three years may be advisable, but this should be phased out as soon as possible.

- 4. Minimum content legislation can be an effective tool in promoting the recycling of plastic.
 - NERC can coordinate legislative initiatives within its membership, and beyond, so that the manufacturers of plastic products are not faced with multiple state standards for recycled content of products.
 - A recycled content of 10 percent for plastic products with narrow resin specifications is reasonable and technically feasible, assuming a clear supply of PCR is available. An exception for products requiring Food and Drug Administration approval would have to be allowed. Percentages in excess of 10 percent are not technically feasible for many products at the present time.
 - NERC should be aware that the timing and structure of minimum content legislation is very important. Commodity prices, such as those for virgin resin, tend to be cyclical. The current low price of virgin resin is forcing the price of recycled resin down. Legislation providing price supports or other incentives may not be necessary when the price for virgin resin cycles upward.

Executive Summary

5. Along with coordinating minimum content legislation, NERC could also promote and coordinate labeling standards, so that manufacturers and consumers would have a clear understanding of the recycled content of plastic packages and products.
6. Certain technical problems in recycling plastic, such as the degradation of plastic as it is recycled, must be solved by the industry. NERC may wish to encourage research and development by industry in areas such as:
 - Sorting technologies
 - Application of technologies for upgrading or improving recycled resins to meet higher performance standards
 - Development of new products specifically designed for recycled plastics
 - Development of improved manufacturing processes for fabricating recycled resins into finished products
 - Commercialization of depolymerization technologies to increase the quality of PCR.
7. Governments should provide incentives to manufacturers encouraging them to test market new products using high percentages of PCR.

Section 1

GENERATION AND SUPPLY OF PLASTICS

INTRODUCTION

The availability of postconsumer plastic scrap for recovery by residential recycling programs in the Northeast depends primarily on five factors.

First, it depends on the amount of plastic which enters the stream of commerce. The total amount of plastic which is sold to consumers in the form of various products is the potential supply of material.

Second, availability depends on when and how much of these plastic products are disposed of in the residential waste stream. Plastic products, such as packaging, are disposed of more quickly after purchase than products such as refrigerators and computers. Certain products, such as automobile parts, are disposed of in special facilities along with the rest of the automobile. Attempts are now being made to recover plastic parts before the automobile is crushed or shredded. Nevertheless, these parts would not be available for recovery through curbside collection programs.

Third, availability depends on how much of the disposed of postconsumer plastic scrap can actually be cost effectively collected. Problems with contamination, or difficulties that residents have in identifying certain kinds of plastic, for example, may diminish the amount which can be collected. In many instances, difficulties are the result of less than effective educational efforts.

Fourth, recovery depends on adequate sorting and processing capacity. Plastic many times require extensive preparation before it can be resold to manufacturers.

Fifth, recovery depends on ready markets for the processed plastic.

The following discussion of the availability of plastic address the first three steps in the five-step process outlined above and focuses on seven major resins:

- Polyvinyl Chloride ("PVC")
- Polypropylene ("PP")

Section 1

- High Density Polyethylene ("HDPE")
- Low Density Polyethylene ("LDPE")
- Linear Low Density Polyethylene ("LLDPE")
- Polystyrene ("PS")
- Polyethylene Terephthalate ("PET").

To obtain an estimate of the amount of plastic entering the stream of commerce, sales of resins and products for 1990 are reviewed and discussed. The focus of this discussion will be on plastics in the residential waste stream. The sales of non-durable and durable consumer products will be emphasized with only occasional references to commercial/industrial products. This discussion of plastic sales will cover each of the seven resins individually.

Next, the quantity and composition of plastic disposed of, as reported by a recent waste composition study conducted for the State of Rhode Island, will be examined. This discussion of plastic in the waste stream will be supplemented by a discussion of seasonality of plastic disposal through the year.

Third, the results of two collection programs will be reviewed to indicate the amounts of plastic recovered in operating collection programs.

In addition to providing a picture of the movement of postconsumer plastic from the marketplace to recycling collection programs, this discussion will suggest resins and products which hold promise for recovery as municipal recycling programs expand.

AVAILABILITY OF PLASTIC RESINS AND PRODUCTS BASED ON SALES FOR 1990

The plastics industry estimates that approximately 56 billion pounds of plastic was sold in the United States in 1990. The seven resins under discussion accounted for approximately 72 percent of this amount. The resins were sold in the form of durable consumer products, non-durable consumer products, and commercial/industrial products. Information on plastics sales for 1990 is based on figures published in Modern Plastics (January, 1991).

Because of the complex movement of plastic from reclaimers and virgin resin producers to plastic product manufacturers to consumers, it is not

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possible to determine the exact amount of plastic sold on a regional basis. However, using a national per capita average for resin sales, it is possible to develop a regional estimate of plastic sales. Although this approach ignores regional differences, it can provide an order-of-magnitude estimate of plastic consumption.

To develop this per capita approach, the population estimates for the Northeastern states shown in Table 1-1 have been used.

Table 1-1
Populations of Northeastern States

Number of Persons	
Connecticut	3,287,116
Delaware	666,168
Maine	1,227,928
Massachusetts	6,016,425
New Hampshire	1,109,252
New Jersey	7,730,188
New York	17,990,455
Pennsylvania	11,881,643
Rhode Island	1,003,464
Vermont	562,758
TOTAL	51,475,397

1990 Census Population for the United States is 249,632,692.

Source: United States Census Bureau

Based on these figures, the Northeast accounts for about 21 percent of the population of the United States. Table 1-2, below shows the total 1990 sales of plastic by resin, the per capita sales of these resins, and the estimated sales in the Northeast.

While Table 1-2 provides an overview of the sale of resins within the United States and the Northeast region, it does not provide information on the common product types for each resin or the fabrication technology employed to turn feedstock into usable products. This information will be presented as a part of a more detailed description for each resin.

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Table 1-2
Sales of Plastic Resins

Resin	Total 1990 Sales in the U.S. (millions of lbs)	U.S. Per Capita Sales ⁽¹⁾ (lbs)	Northeastern Sales ⁽²⁾ (millions of lbs)	Percent of Total Northeastern Sales
PVC	8,360	33.5	1,724	21.23
PP	6,592	26.4	1,359	16.73
HDPE	7,793	31.2	1,607	19.79
LDPE	5,403	21.6	1,114	13.72
LLDPE	4,403	17.6	908	11.18
PS	4,941	19.8	1,019	12.55
PET	1,889	7.6	390	4.80
TOTAL	39,381	157.7	8,121	100.00
Northeast as a Percentage of United States Sales = 21%				

⁽¹⁾ Based on population per 1990 United States Census.

⁽²⁾ Based on national per capita sales estimates and Northeast population estimates shown in Table 1-1.

Source: *Modern Plastics*, January 1991

Below, each of the seven resins is discussed individually. The use of the resin by fabrication technology and product type, in terms of 1990 sales, is presented. A brief description of the fabrication technologies is included in Appendix A. The type of fabrication used with a resin can be important because, in some cases, products made from the same resin, but with a different fabrication technology, are not compatible for recycling. For example, the remelted resins from HDPE blow-molded milk jugs and injection-molded HDPE margarine tubs are not compatible, except for mixed resin applications, such as plastic lumber.

The products have also been subdivided into three categories. The first category, non-durable consumer goods, includes those products which would be disposed of within two years of purchase and would normally be found in the residential waste stream. Consumer packaging, toys, housewares, and containers would be part of this category. The second category is durable consumer goods, including furniture, appliances, and computers. These products would normally be disposed of more than two

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years after purchase. The remaining products have been categorized as commercial/industrial. These include water pipe, siding, and machinery parts. Where the definition of the product was unclear, such as those labeled "other," the commercial/industrial designation has been used. Exports are shown separately. A summary of all resins by product category is presented at the end of this section, and a more detailed set of tables is included in Appendix B.

SUMMARY OF 1990 PLASTIC SALES

Ranking the sales of the seven resins by product category suggests that HDPE has excellent potential as a targeted recyclable. Table 1-3 presents the ranking for non-durable consumer products.

Table 1-3
Summary Table of Resin Usage for Manufacture of
Non-Durable Consumer Products

Resin Type	1990 U.S. Sales	Percent of Total Non-Durable Sales
HDPE	3,770	28.47
LDPE	1,889	14.27
PS	2,196	16.58
LLDPE	1,801	13.60
PET	1,759	13.28
PP	1,083	8.18
PVC	743	5.61
TOTAL	13,241	100.00

Source: *Modern Plastics*, 1991

More than 28 percent of the HDPE sold was made into blow-molded bottles, and injection-molded caps, tubs, and other containers. Many residential recycling programs are already collecting HDPE, either as milk jugs or with other rigid containers. Most of the LDPE and LLDPE was made into film which presents special recovery problems which will be discussed in Section 2. PS also seems to hold promise for recovery

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because it makes up about one-sixth of the resins used domestically to produce non-durable consumer products. In addition, PS is also used for more than half of the durable consumer goods made, as Table 1-4 shows. However, there are significant problems in cleaning and transporting PS. PET soft drink bottles are currently recovered through bottle deposit programs in the nine states with deposit legislation and in many residential recycling programs. Based on the figures in Table 1-3, PVC and PP appear to have less potential as a targeted recyclable material in residential recycling programs than the other resins because of their limited application in non-durable consumer goods. The percent of non-durable, and durable, products in the waste stream may fluctuate over time with changes in the market share of these products. Appendix C describes this fluctuation in more detail.

Table 1-4
Summary Table of Resin Usage for the Manufacture of
Durable Consumer Products

Resin Type	1990 U.S. Sales	Percent of Total Durable Sales
PS	807	53.20
PP	398	26.24
PVC	312	20.57
HDPE	0	0.00
LLDPE	0	0.00
LDPE	0	0.00
PET	0	0.00
TOTAL	1,517	100.00

Source: *Modern Plastics*, 1991

POLYVINYL CHLORIDE

PVC can be used for a wide range of products by blending it with various additives. When used in products such as irrigation pipe, house siding, and credit cards, it is a tough plastic with a smooth finish which scratches easily. However, it can also be used in applications which require flexibility, such as medical tubing, packaging film, and shower curtains.

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As Table 1-5 shows, a wide variety of fabrication technologies is used with PVC. Although most PVC is extruded into pipe, siding, and cable, it is also molded to make electronic components, phonograph records, and traffic cones.

Table 1-5
Fabrication of PVC in the United States

Technology	Total 1990 Sales ⁽¹⁾	Percent of Total PVC Resin Sales
Calendering	1,053	11.33
Extrusion	5,973	64.25
Injection Molding	420	4.52
Blow Molding	223	2.40
Compression Molding	20	0.22
Dispersion Molding	225	2.42
Dispersion Coating	381	4.11
Vinyl Latexes	65	0.69
Subtotal-Domestic Sales	8,360	89.92
Export	937	10.08
TOTAL	9,297	100.00

⁽¹⁾ Millions of pounds.

Source: Modern Plastics, 1991

Most PVC products, more than 75 percent, are commercial/industrial applications, as Table 1-6 indicates.

Non-durable consumer products made with PVC are primarily blow-molded bottles for consumer products. Most PVC applications for durable consumer products are for furniture and furnishings.

Although more PVC was sold in 1990 than any of the other seven resins under discussion, it appears to have limited potential for residential recycling, based on these tables. The consumer product applications were a modest 11 percent of total sales. The large volume of commer

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Table 1-6
United States Fabrication By Product Category for PVC

Product Type	1990 Sales (1)	Per Capita Sales	Percent of Total PVC Resin Sales
Non-Durable Consumer	743	3.0 lbs	8.0
Durable Consumer	312	1.2 lbs	3.4
Commercial/Industrial	7,305	29.3 lbs	78.6
Subtotal - Domestic Sales	8,360	33.5 lbs	89.9
Export	937		10.1
TOTAL	9,297		100.0

(1) Millions of pounds.

Source: Modern Plastics, 1991

cial/industrial applications suggests that PVC generators might be targeted by commercial recycling programs.

POLYPROPYLENE

PP is a tough, hard plastic which does not scratch. It can be tailored for use in many fabrication methods and applications, has good tensile strength, and good resistance to chemicals and heat. Most PP is extruded into fibers and filaments.

A large volume was also exported in 1990 as Table 1-7 shows.

Like PVC, most PP is used largely in commercial/industrial applications, as Table 1-8 shows.

Non-durable consumer products made from PP include bottles, toys, and housewares. Durable consumer products include furniture, appliances, and automobile battery cases. Currently, automotive battery cases are being recovered at a rate of almost 90 percent.

Based on these generation figures, PP holds limited promise as a recoverable material from the residential waste stream. A relatively small percentage of total non-durable consumer products are PP, only 8 percent. Injection molded PP is used in the manufacture of major appliances such

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Table 1-7
Fabrication of PP in the United States

Technology	Total 1990 Sales ⁽¹⁾	Percent of Total PP Resin Sales
Extrusion	3,034	37.3
Injection Molding	1,940	23.9
Blow Molding	148	1.8
Other	1,470	18.1
Subtotal - Domestic Sales	6,592	81.1
Export	1,540	18.9
TOTAL	8,132	100.0

⁽¹⁾ Millions of pounds.

Source: Modern Plastics, 1991

Table 1-8
United States Fabrication by Product Category for PP

Product Type	1990 Sales ⁽¹⁾	Per Capita Sales	Percent of Total PP Resin Sales
Non-Durable Consumer	1,083	4.3 lbs	13.3
Durable Consumer	398	1.6 lbs	4.9
Commercial/Industrial	5,111	20.5 lbs	62.9
Subtotal-Domestic Sales	6,592	26.4 lbs	81.1
Export	1,540		18.9
TOTAL	8,132		100.0

⁽¹⁾ Millions of pounds.

Source: Modern Plastics, 1991

as refrigerators. Like PVC, most PP is used primarily for commercial/industrial products.

HIGH DENSITY POLYETHYLENE

Natural HDPE is a translucent, milky white material with excellent resistance to most industrial and household chemicals. Its most recognizable use is in milk and water jugs, but it has many other packaging applications such as margarine tubs and garment bags.

Table 1-9
Fabrication of HDPE in the United States

Technology	Total 1990 Sales ⁽¹⁾	Percent of Total HDPE Resin Sales
Blow Molding	2,910	34.22
Extrusion	2,054	24.15
Injection Molding	1,580	18.58
Rotomolding	75	0.88
Other	1,174	13.80
Subtotal-Domestic Sales	7,793	91.63
Export	712	8.37
TOTAL	8,505	100.00

⁽¹⁾ - Millions of pounds.

Source: *Modern Plastics*, 1991

HDPE's blow-molded applications are primarily product containers such as milk and water jugs and bottles for household chemicals. Extruded HDPE is commonly used for merchandise film bags, grocery sacks, and toys for consumers. Industrial applications for extruded HDPE include corrugated pipe, wire and cable, and sheet. HDPE can also be injection molded into pails, tubs, and soft drink bottle base cups. As Table 1-10 shows, HDPE is used exclusively for non-durable consumer products and commercial/industrial products.

HDPE has potential as an excellent resin to target for recycling because of its many non-durable consumer product applications. Many municipal recycling programs are currently targeting HDPE milk and water jugs for collection. Some municipal programs are also collecting HDPE detergent

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Table 1-10

United States Fabrication by Product Category for HDPE

Product Type	1990 Sales ⁽¹⁾	Per Capita Sales	Percent of Total HDPE Resin Sales
Non-Durable Consumer	3,770	15.1 lbs	44.3
Durable Consumer	0	0.0 lbs	0.0
Commercial/Industrial	4,023	16.1 lbs	47.3
Subtotal-Domestic Sales	7,793	31.2 lbs	91.6
Export	712		8.4
TOTAL	8,505		100.0

⁽¹⁾ Millions of pounds.

Source: Modern Plastics, 1991

bottles and shampoo bottles. A few supermarket chains are also collecting grocery sacks for recycling. More than one-quarter of all non-durable consumer products manufactured from the seven resins discussed in this report are made from HDPE.

LOW DENSITY POLYETHYLENE

LDPE can be made into a light, flexible film which can be translucent or opaque. Like all other resins, it can also be pigmented. It may also have a high or low gloss finish. As Table 1-11 shows, more than three-quarters of LDPE is extruded, mostly into packaging film.

Based on sales of material, LDPE appears to be an excellent resin to target for recycling. As Table 1-12 shows, 1.9 billion pounds of LDPE is used for non-durable consumer products. Most of this is for film products. However, the difficulty in separating and cleaning "dirty" film has impeded the recovery of this resin. This will be discussed in more detail in Section 2.

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Table 1-11
Fabrication of LDPE in the United States

Technology	Total 1990 Sales ⁽¹⁾	Percent of Total LDPE Resin Sales
Blow Molding	62	1.00
Extrusion	4,591	74.41
Injection Molding	296	4.80
Rotomolding	196	3.18
Other	367	5.95
Subtotal-Domestic Sales	5,408	89.34
Export	720	11.67
TOTAL	6,170	100.00

⁽¹⁾ Millions of pounds.

Source: Modern Plastics, 1991

Table 1-12
United States Fabrication by Product Category for LDPE

Product Type	Total 1990 Sales ⁽¹⁾	Per Capita Sales	Percent of Total LDPE Resin Sales
Non-Durable Consumer	1,889	7.6 lbs	30.6
Durable Consumer	0	0.0 lbs	0.0
Commercial/Industrial	3,623	14.5 lbs	58.7
Subtotal-Domestic Sales	5,512	22.1 lbs	89.3
Export	720		11.6
TOTAL	6,170		100.0

⁽¹⁾ Millions of pounds.

Source: Modern Plastics, 1991

LINEAR LOW DENSITY POLYETHYLENE

As its name suggests, this resin is closely related to LDPE. Both are used to make packaging film. In LLDPE, the polymer backbones of the resin are closely packed in a more linear fashion to provide higher tensile strength and better puncture resistance and tear qualities. It is not as clear as LDPE, but the two can be blended to combine the properties of both. When LDPE and LLDPE are mixed, they are typically combined in a ratio of 4 (LDPE) to 1 (LLDPE). When larger amounts of LLDPE are used, it can cause production difficulties or loss of clarity. This limitation may be a barrier to the recovery of mixed film.

Table 1-13
Fabrication of LLDPE in the United States

Technology	Total 1990 Sales ^[1]	Percent of Total LLDPE Resin Sales
Blow Molding	28	0.60
Extrusion	3,127	67.13
Injection Molding	537	11.53
Rotomolding	124	2.66
Other	587	12.60
Subtotal-Domestic Sales	4,403	94.53
Export	255	5.47
TOTAL	4,658	100.00

^[1] Millions of pounds.

Source: *Modern Plastics*, 1991

The product applications for LLDPE, not surprisingly, are very similar to those of LDPE, making it difficult to sort effectively.

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Table 1-14
United States Fabrication by Product Category for LLDPE ^[1]

Product Type	1990 Sales ^[2]	Per Capita Sales	Percent of Total LLDPE Resin Sales
Non-Durable Consumer	1,801	7.2 lbs	38.7
Durable Consumer	0	0.0 lbs	0.0
Commercial/Industrial	2,602	10.4 lbs	55.9
Subtotal-Domestic Sales	4,403	17.6 lbs	94.5
Export	255		5.5
TOTAL	4,658		100.0

^[1] Millions of pounds.

Source: Modern Plastics, 1991

POLYSTYRENE

This resin can be fabricated as either a solid or a foam. In its solid state, it is hard, smooth, and brittle, with good scratch-resistant qualities. It can be made either clear or opaque. As a foam, it is light and can absorb shock. The high volume to weight ratio of PS foam makes it very expensive to transport unless densified. The foam is generally white, although it can be pigmented. Solid PS accounts for about 64 percent of all PS product applications, as Table 1-15 shows.

Most PS is used for non-durable consumer products, which suggests that it holds promise as a recyclable resin, if barriers to recovery, such as food contamination and the high cost of transport for foam food service applications, can be overcome.

Non-durable consumer products made from PS include packaging filler and food service products, like coffee cups and plastic cutlery. The Polystyrene Packaging Council estimates that there are at least 30 school districts in New Jersey, New York, Massachusetts, and Pennsylvania collecting PS. Molded furniture, a durable consumer product, is made from PS.

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Table 1-15
Fabrication of PS in the United States

Technology	Total 1990 Sales ⁽¹⁾	Percent of Total PS Resin Sales
Molding (solid)	1,879	36.58
Extrusion (solid)	1,415	27.55
Extrusion (foam)	737	14.35
Expandable Bead (foam)	659	12.83
Other	251	4.89
Subtotal-Domestic Sales	4,491	96.18
Export	196	3.82
TOTAL	5,137	100.00

⁽¹⁾ Millions of pounds.

Source: Modern Plastics, 1991

Table 1-16
United States Fabrication by Product Category for PS

Product Type	1990 Sales ⁽¹⁾	Per Capita Sales	Percent of Total PS Resin Sales
Non-Durable Consumer	2,196	8.8 lbs	42.8
Durable Consumer	807	3.2 lbs	15.7
Commercial/Industrial	1,938	7.8 lbs	37.7
Subtotal-Domestic Sales	4,941	19.8 lbs	96.2
Export	196		3.8
TOTAL	5,137		100.0

⁽¹⁾ Millions of pounds.

Source: Modern Plastics, 1991

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POLYETHYLENE TEREPHTHALATE

PET is a clear, lightweight, shatter-resistant plastic which has good chemical resistance and can act as an effective gas barrier. It is most visible as the material from which plastic blow-molded soft drink bottles are manufactured, but it has a variety of other uses, such as fiber, peanut butter jars and bottles for pharmaceuticals and vitamins. It is extruded to produce film and recording tape. (See Table 1-17) PET appears to hold considerable promise as a recyclable resin, despite relatively small amounts sold, because more than 80 percent of product applications are non-durable consumer products. (See Table 1-17)

Table 1-17
Fabrication of PET in the United States

Technology	Total 1990 Sales ⁽¹⁾	Percent of Total PET Resin Sales
Blow Molding	1,089	50.9
Extrusion	675	31.6
Coating	11	0.5
Sheeting	80	3.7
Strapping	34	1.6
Subtotal-Domestic Sales	1,889	88.3
Export	250	11.7
TOTAL	2,139	100.0

⁽¹⁾ Millions of pounds.

Source: *Modern Plastics*, 1991

Table 1-18
United States Fabrication by Product Category for PET

Product Type	1990 U.S. Sales ⁽¹⁾	Per Capita Sales	Percent of Total PET Resin Sales
Non-Durable Consumer	1,759	7.1 lbs	82.2
Durable Consumer	0	0.0 lbs	0.0
Commercial/Industrial	130	0.5 lbs	6.1
Subtotal-Domestic Sales	1,889	7.6 lbs	88.3
Export	250		11.7
TOTAL	2,139		100.0

⁽¹⁾ Millions of pounds.

Source: Modern Plastics, 1991

It has already been pointed out that the sale of resins is only the first step in determining the availability of plastic scrap. The next step is to consider waste composition studies to determine what is actually in the waste stream. The results of the Rhode Island Waste Composition Study will be used as a basis for this.

PLASTIC DISPOSED OF (RHODE ISLAND WASTE COMPOSITION STUDY)

The State of Rhode Island conducted a waste sampling study¹ in 1990 to determine the composition of the three major waste streams in the State:

- municipal waste, which was primarily residential waste;

¹ Rhode Island Solid Waste Composition Study Final Report, Rhode Island Solid Waste Management Corporation, 260 West Exchange Street, Providence, Rhode Island 02903, October 17, 1990, conducted by SCS Engineers.

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- mixed waste, which was a combination of commercial and residential waste; and
- commercial waste, which consisted of specialized loads of one or two materials.

The focus of this discussion will be the municipal waste stream because it includes most of the residential waste.

In the Rhode Island Study, plastic comprised 8.8 percent of the municipal waste stream by weight, averaged over the four seasons. During 1990, a total of 460,000 tons of municipal waste was disposed of at Rhode Island's Central Landfill. (The Study reported approximately 90 percent of all the municipal waste generated in the State is disposed of at the Central Landfill.)

Based on these figures, the total amount of plastic disposed of at the Central Landfill was approximately 40,464 tons. Assuming that Rhode Island's population is 1,003,000, this would result in a residential per capita disposal rate of 80.7 pounds per person for 1990.

The per capita sales rate, based on all plastics sold in 1990, was about 224 pounds. Table 1-19 shows other per capita sales figures.

Table 1-19
1990 U.S. Sales of Plastic Resins

Plastic Resins	Total 1990 Sales (millions of lbs)	Per Capita 1990 Sales ^[1] (lbs)
All Plastics	56,055	224
Non-Durables	14,042	56
Durables	3,347	13
Commercial/Industrial	38,666	155
Seven Resins	40,371	162
Non-Durables	13,910	56
Durables	1,517	6
Commercial/Industrial	24,944	100

^[1] Based on 1990 United States census population of 249,632,692.
Sources: *Modern Plastics*, 1991, R. W. Beck and Associates.

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If Rhode Island's annual per capita plastic disposal rate of 81 pounds is accurate, it would appear that, in addition to durable and non-durable consumer products, some plastics from commercial/ industrial applications were also disposed of in the municipal waste stream since the sales data summarized in Table 1-19 show that only 69 pounds per capita of residential durables and non-durables are sold each year. In addition, plastics other than the seven resins under discussion in this Report contributed to the plastic waste stream.

A more detailed study of the plastics stream was undertaken for the summer, fall, and winter sorting periods. The 12 categories of resin/product used to sort the plastics were as follows:

- PVC
- PP
- HDPE - Translucent
- HDPE - Pigmented
- LDPE
- PS
- PET - Clear
- PET - Pigmented
- Disposable Food Accessories
- Thermoset Plastics
- Films
- Other Plastics.

In order to compare the generation figures derived from 1990 sales data and the waste generation figures, these categories have been aggregated as follows:

- PVC
- PP
- HDPE (includes both translucent and pigmented)
- LDPE and LLDPE (includes film)

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- PS (includes disposable food accessories)
- PET (includes both clear and pigmented)
- Other.

Table 1-20 compares the generation based on 1990 national industry sales data and disposal figures from the Rhode Island Study.

Table 1-20
Comparison of 1990 Sales and Disposal Figures
(pounds)

Resin/Product	National Per Capita Sales of Non-Durable Products ^[1]	Rhode Island Per Capita Disposal of Resin ^[2]	Rhode Island Per Capita Recovery MRF ^[3]
PVC	3.0	0.9	0.0
PP (ex. film)	4.3	1.2	0.0
HDPE (ex. film)	12.6	11.0	1.6
LDPE (ex. film)	0.0	0.5	0.0
PS	8.8	5.5	0.0
PET (ex. film)	4.9	4.4	1.9
Film	22.2	39.3	0.0
Subtotal	55.7	62.7	3.5
Other Plastic		10.7 ^[4]	
Contaminants		7.3	
TOTAL	55.7	80.7	

^[1] Based on non-durable consumer products (as shown in Table 1-17) sold in 1990 and United States population of 249,632,692.

^[2] Based on 8.8 percent (by weight) of plastic in the municipal waste stream, percentages for plastic sub-sort with contamination, 460,000 tons of municipal waste disposed at the Central Landfill, and Rhode Island population of 1,003,000.

^[3] Sixty-five percent of the population was recycling at the time of the study. Rhode Island does not have a bottle bill. Plastic soda bottles and milk jugs have been collected once a week in blue boxes at curbside on the regular garbage pickup day since the program began in 1987.

^[4] Includes thermoset plastics and other resins and products not included above.

Source: Modern Plastics, 1991

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Table 1-20 is based on several key assumptions which include

- The accurate assigning of "non-durable consumer," "durable consumer product," and "commercial/industrial product" designations based on the fabrication and product labels given in Modern Plastics.
- The Central Landfill received all residential waste in Rhode Island. The State of Rhode Island has estimated that 90 percent of the municipal solid waste is disposed of at the Central Landfill.
- All disposable food service products sorted in the waste composition study were PS.

Therefore, the figures should not be viewed as exact. They can, however, be used to indicate the relationships among the sale and disposal of these resins.

The total HDPE (excluding film) estimated to be disposed of at the Central Landfill and recovered at the MRF was 12.6 pounds per capita, equal to the national sales average for HDPE non-durables.

Similarly, the total amount of PET estimated to be disposed of at the Central Landfill and recovered at the MRF on a per capita basis was 6.3 pounds, higher than the 4.9 pounds which is the national sales average for PET non-durables (excluding film). Differences between national sales and actual Rhode Island sales may account for this discrepancy.

A major discrepancy in Table 1-20 is the difference between the amount of film sold in the United States in 1990 and the amount of film estimated to be disposed of. Based on the Rhode Island Waste Composition Study, the amount of film which was disposed of was more than one and a half times the national sales average on a per capita basis, although there is no obvious explanation for this. This could be partially accounted for by contamination to the film. Despite efforts to remove contamination, food scraps and moisture often cling to film plastic which is being sorted. Also, dirt in the corners of trash bags increases the apparent weight of film products. However, these problem areas are unlikely to account for this wide a difference.

The 13 percent of material disposed of in the "Other Plastic" category includes both thermoset plastics and plastics not otherwise categorized.

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These could include other resins, or resins which were uncoded or unrecognizable.

On the basis of these disposal figures, the resins with the greatest potential for recovery appear to be the same ones as those identified on the basis of 1990 sales. Again, film plastics, as represented by LDPE and LLDPE are the most plentiful resins. HDPE is also plentiful, even though significant amounts of milk and water jugs were being recycled during the period of the waste composition study. PS and PET also seem to be promising. The small amounts of PVC and PP suggest that these resins may be costly to recover, relative to the other plastic resins.

SEASONALITY

In addition to knowing how much plastic scrap is available for recovery, it might also be useful to know whether this availability changes significantly over the year. Peaks and valleys in disposal rates could have an impact on the sizing of facilities and the marketing of materials.

Seasonality might occur in two ways. First, there might be a sharp change in the rate of disposal of all plastics in one particular season. For example, the amount of plastic in the waste stream, as indicated by its fraction of the waste stream, might increase dramatically in the summer and then decrease in the fall and winter.

Table 1-21 shows that plastic, as a percentage of the municipal waste stream, showed modest variation through the seasons, in relation to other materials. Yard Waste, Paper, and "Other," all show variations in the range of 6 to 7 percentage points. Plastic, Metals, and Glass vary from 1 to 3 percentage points. There does not appear to be evidence of strong seasonality for all plastic scrap.

The second way in which seasonality might occur is within the plastic stream. That is, individual resins or products might have varied significantly, even though plastic as a whole does not. Unfortunately, a single three-season study does not provide enough data points to conclude that there is a statistically significant variation in the disposal of individual resins/products. A multi-season sampling program carried out over three to five years would be necessary to establish seasonality with a high degree of confidence.

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The results of the three-season sampling program do indicate that there was significant variation in some resins/products. Table 1-22 shows the composition of the plastic stream for the summer, fall, and winter sorting periods, as well as the three-period average.

Table 1-21
Seasonal Variation in Plastics
Rhode Island Waste Composition Study

Product/Resin	Summer Sort 1	Fall Sort 2	Winter Sort 3	Three-Season Average
PVC	1.00%	1.30%	1.30%	1.20%
PP	2.70%	1.10%	1.20%	1.67%
HDPE - Translucent	4.10%	5.10%	4.30%	4.50%
HDPE - Pigmented	12.40%	9.50%	9.30%	10.40%
LDPE	0.80%	0.40%	0.90%	0.70%
PS	4.30%	3.10%	3.10%	3.50%
PET - Clear	4.90%	4.90%	4.50%	4.77%
PET - Pigmented	1.60%	1.00%	1.00%	1.20%
Disposable Food	4.50%	4.00%	3.40%	3.97%
Thermoset	0.80%	0.40%	1.00%	0.73%
Films	48.40%	55.60%	56.20%	53.40%
Other	14.20%	13.50%	13.80%	13.83%
TOTAL	99.70%	99.90%	100.00%	99.87%

Source: Rhode Island Waste Composition Study.

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PLASTICS COLLECTED (HIGHLAND PARK, NEW JERSEY AND MINNEAPOLIS, MINNESOTA)

The generation of plastics, as reported in sales figures, and the disposal of plastics, as reported in waste composition studies, suggest the potential amount of material available for recycling. A more accurate estimate of the amount of material which is actually recoverable can be obtained by looking at collection programs. Figures for plastic collected can provide an indication of how much municipal programs might expect to collect. Two of the municipal recycling programs which have conducted studies of the amount of plastic collected have been used below.

Highland Park, New Jersey

The first program was conducted by Professor Neale Merriam of Rutgers University. One hundred and two homes in Highland Park, New Jersey were studied for ten months in 1990. Highland Park is a middle-class suburb, just northeast of New Brunswick, New Jersey. It is served by a twice monthly curbside program which collects ONP, glass, ferrous and aluminum cans, as well as plastics. The recycling program has been operational for two years. Four hundred households were asked to place "all clean plastic" out for collection. The Study sampled 102 of the 400 households for a period of three months. The plastic stream was subdivided into 11 categories. Table 1-22 shows the results from this study.

The figures in Table 1-22 indicate there are two factors which influence collection. The first is the amount of material available in the waste stream. For example, the recovery of large amounts of HDPE, 37 percent of the total material collected, reflects the high percentage of non-durable HDPE consumer products in the stream of commerce. Similarly, the relatively small amounts of PP and PVC in the waste stream are reflected in the small amounts collected.

The second factor which influences recovery is the ease with which residents can identify and separate certain resins/products. For example, the amount of plastic film collected is not consistent with the amount generated and disposed of. This may be due, in part, to the difficulty residents have in cleaning and handling plastic film. On the other hand,

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the amount of PET soft drink bottles collected appears to be greater than one might expect, based on generation and disposal figures. This high collection rate may be the result of the ease in handling the bottles. It should also be noted that the high rate of recovery can be attributed, in part, to the fact that New Jersey does not have a bottle deposit law. States with deposit legislation would collect fewer PET bottles.

Table 1-22
Plastics Collected - Highland Park, New Jersey

Resin/Product	Pounds per Person per Year	Percent of Total	Percent of Rigids
HDPE Milk/Water	2.3	17.6	24.0
PET Soda Bottles	2.6	20.3	27.7
Subtotal Soda/Milk/Water	4.9	37.9	51.6
PVC Bottles	0.2	1.9	2.6
PP Bottles	0.1	0.7	1.0
HDPE Colored	2.6	20.0	27.2
PS Thermoform/Foam	0.6	4.8	6.5
PET Other	0.5	3.5	4.8
Composite Bottles	0.1	0.5	0.7
Miscellaneous Tubs	0.5	4.1	5.6
Total Rigids	9.5	73.4	100.0
Films (mostly PET)	1.7	13.3	
Durables/Non-Durables	1.7	13.3	
TOTAL COLLECTED	13.0	100.0	

Source: Collection of all clean plastic; Center for Plastics Recycling Research, 1990

Minneapolis, Minnesota

The second collection study was conducted in Minneapolis, Minnesota during the first four months of 1991 with 2,586 urban households participating. Minneapolis has provided curbside collection of recyclables since 1981. It collects materials every other week and added plastics in

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November of 1990. Residents were instructed to place "all bottles with necks" on the curb for collection. This included PET soft drink bottles, milk jugs, and detergent bottles. It did not include wide-mouth rigid containers, such as margarine tubs and peanut butter jars. Minnesota does not have a bottle bill. Note: the Minneapolis Study also divided plastics into 11 categories, plus three categories of contaminants and residue. As Table 1-23 shows, the 11 plastic categories of the two studies were not identical.

Table 1-23
Plastics Collected - Minneapolis, Minnesota

Resin/Product	Pounds per Person per Year	Percent of Total	Percent of Rigid
HDPE Milk/Water	2.0	24.4	29.1
PET Soda Bottles	1.7	19.8	23.6
Subtotal Soda/Milk/Water	3.7	44.2	52.7
PVC Bottles	0.2	2.2	2.6
PP Bottles	0.1	1.0	1.2
HDPE Colored	1.4	16.1	19.2
HDPE Other	0.1	0.8	1.0
PS Thermoform/Foam	0.2	2.6	3.1
PET Other	0.1	1.2	1.4
Composite Bottles	0.1	1.0	1.2
Unknown Bottles	0.9	11.1	13.2
Unknown Non-Bottles	0.3	3.7	4.4
Total Rigid	7.0	83.9	100.0
Lids & Caps	0.4	4.7	
Contaminants	0.1	0.9	
Residue	0.9	10.5	
TOTAL COLLECTED	8.4	100.0	

Source: *Characterization of Post-Consumer Plastics Collected within the City of Minneapolis; Council for Solid Waste Solutions; 1991*

As Table 1-23 shows, the Minneapolis program collected less plastics per capita, although the percentages of each material are quite similar. In

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Highland Park, slightly more PET (soft drink bottles) was collected than HDPE (milk/water); in Minneapolis, the reverse was true. Minneapolis did not collect film, nor did Highland Park record contaminants and residue.

SUMMARY: PLASTIC AVAILABLE FOR RECOVERY

The available supply of post-consumer plastic scrap has been examined from three perspectives. First, the amounts of resins and products in the stream of commerce were estimated, using the 1990 sales figures for plastic. Second, the amount of plastic in the waste stream was reported, using Rhode Island's four-season waste composition study. Third, the amount of plastic collected was reported from two recycling programs - one in Highland Park, New Jersey and the other from Minneapolis, Minnesota.

About 56 billion pounds of plastic was sold in 1990 in the United States, a per capita rate of approximately 224 pounds. The total sales of the seven resins under discussion was 39.4 billion pounds, a per capita rate of 158 pounds. The plastics available for recycling are most likely to be consumer products, primarily the non-durable products such as packaging, with a per capita sales rate of 53.1 pounds per person. The total amount of consumer non-durable products made from the seven resins was 13.2 billion pounds. The per capita rate for each resin is shown in Table 1-24.

The amount of this material which will actually appear in the residential waste stream will depend on several factors. Some of these products may be disposed of as commercial/industrial waste, even though they are consumer products. For example, some plastic soft drink bottles will be discarded at a construction site and be disposed of along with the construction and demolition debris. Some products may never be properly disposed of, but will be thrown along the road or in the ocean.

With the exception of the film plastic, the amount of plastic disposed of, as reported in Rhode Island's Waste Composition Study, or recovered through recycling, was comparable to the total amount of non-durable consumer products sold in 1990, As shown in Table 1-20. The amount of PET disposed of or recycled is slightly greater than national sales and rates.

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Table 1-24
Per Capita Sales of Seven Plastic Resins ^[1]

Resin	Total Non-Durable Consumer Products (millions of lbs)	1990 Sales per Capita (lbs)
PVC	743	3.0
PP	1,083	4.3
HDPE	3,770	15.1
LDPE	1,889	7.6
LLDPE	1,801	7.2
PS	2,196	8.8
PET	1,759	7.0
TOTAL	13,241	53.1

^[1] Based on 1990 United States Census population of 249,632,692.
Source: Modern Plastics, 1991; United States Census Bureau.

The difference between the amount sold and the amount disposed of or recovered of the first five resins may be the result of imprecision in the data. The significant discrepancy between film sold and film disposed of cannot be explained with the available data.

The amount of residential plastic collected is a fraction of the amount of material sold or disposed of. Not all residents participate in a curbside collection program, and those residents who do often fail to include all of each targeted material. Table 1-25 compares 1990 sales of non-durable consumer products by resin with amounts disposed of and recovered in Rhode Island, and the amount collected in Highland Park, New Jersey and Minneapolis, Minnesota.

As Table 1-25 shows, the total per capita collection of plastic for the first five resins is between 15 percent and 23 percent of plastic sales.

In terms of individual resins, certain resins show a significantly higher recovery rate than others, as Table 1-26 shows.

Part of the explanation for the higher recovery rates of HDPE (32%) and PET (44%) may be that the major products made from these resins are

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Table 1-25
Comparison of Sales
Disposal and Collection of Residential Plastic

Resin	Per Capita Sales for Non-Durable Consumer Products (lbs)	Per Capita Disposed in Municipal Waste Stream (lbs)	Per Capita Recovered from Rhode Island Municipal Waste Stream (lbs)	Per Capita Collected in Highland Park, New Jersey (lbs)	Per Capita Collected in Minneapolis, Minnesota (lbs)
PVC	3.0	0.9	--	0.2	0.1
PP	4.3	1.2	--	0.1	0.2
HDPE	15.1	11.0	1.6	4.9	3.4
PS	8.8	5.5	--	0.6	0.2
PET	7.0	4.4	1.9	3.1	1.8
Subtotal	38.3	23.0	3.5	8.9	5.7
LDPE	7.6				
LLDPE	7.2				
Film		39.8		1.7	
Subtotal	14.8	39.8	--	1.7	0.0
Total for Seven Resins	53.1	62.7	3.5	10.7	5.7
Other Plastics	0.5	10.7	--	2.3	1.3
Residue/Contaminants	NA	7.3	--	0.0	1.4

Source: Rhode Island Waste Composition Study;

Collection of all clean plastic; Center for Plastics Recycling Research, 1990;

Characterization of Post-Consumer Plastics Collected within the City of Minneapolis; Council for Solid Waste Solutions, 1991

Modern Plastics, 1991

easy to identify and easy to handle. They are also relatively plentiful in the plastic stream. The high recovery of these resins is the result of milk and water jugs and soft drink bottles being targets for plastic recycling programs. Conversely, consumer products made from PP and PVC are not particularly plentiful, are more difficult to identify and handle, and have not been a commonly targeted material in recycling programs.

Even though the amount of film products made from LDPE, LLDPE, and other resins was quite large, the amount collected was relatively small. This may be due to the difficulty in handling film and the ease with which film products are contaminated with food. A more complete discussion of the recoverability of plastic resins and products will be the subject of Section 2.

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Table 1-26
Comparison of Plastic Disposed and Collected
As a Percent of Plastic Sold ⁽¹⁾

Resin	Percent Disposed ⁽²⁾	Percent Collected ⁽³⁾
PVC	30	7
PP	28	2
HDPE	73	32
LDPE & LLDPE	229 ⁽⁴⁾	10
PS	63	7
PET	63	44
TOTAL	60	23

⁽¹⁾ Per capita 1990 United States sales figures for non-durable consumer products.

⁽²⁾ Based on composition of municipal waste at Rhode Island's Central Landfill over three seasons in 1990.

⁽³⁾ Based on per capita collection of plastics in Highland Park, New Jersey in 1990.

⁽⁴⁾ The available data show that the amount of film disposed, on a per capita basis, was greater than the national average of film sold.

Source: Rhode Island Composition Study;

Collection of all clean plastic; Center for Plastics Recycling Research, 1991;

Characterization of Post-Consumer Plastics Collected within the City of Minneapolis;

Council for Solid Waste Solutions; 1991

Modern Plastics; 1991

CONCLUSIONS

1. The seven resins which are the focus of this Report accounted for 72 percent of total U.S. sales of plastics in 1990.
2. These seven resins also accounted for about 99 percent of the non-durable consumer products manufactured; about 45 percent of the durable consumer products; and 64 percent of the commercial/industrial products.
3. The three individual resins most commonly found in non-durable consumer products are HDPE, LDPE, and PS.
4. By far, the plastic application accounting for the largest fraction of the plastic waste stream is film. Other easily identifiable plastic products

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which are plentiful in the waste stream are PET soft drink bottles, HDPE bottles for household chemicals, and HDPE milk jugs.

<u>Product</u>	<u>1990 Sales (millions of lbs)</u>	<u>Percent of 1990 Sales</u>
Plastic Film	4,908	7.98
PET soft drink bottles	754	1.23
HDPE household chemical bottles	926	1.51
HDPE milk/water jugs	736	1.20

5. Because HDPE, LDPE and LLDPE film are similar in appearance, residents and businesses will have difficulty distinguishing among them.

RECOMMENDATIONS

1. Based on the amounts of HDPE used for milk and water jugs and the amounts of PET used for soft drink bottles, residential recycling programs should continue to collect these products.
2. Film recycling holds promise as a means of substantially reducing the commercial and institutional plastic waste stream.
3. Because PP and PVC are relatively small fractions of the residential waste stream, these two resins should not be targeted for collection unless an efficient and cost-effective sorting technology can be developed.

Opportunities may exist for recovering PP and PVC in durable products or from commercial/industrial sources.

4. Although the amount of PS sold to consumers and disposed of by residents suggests that this resin could be targeted for recycling, difficulties with collection and contamination make it expensive to recover from the residential waste stream. A more cost-effective approach is

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to identify specific commercial and institutional locations, such as schools, fast-food restaurants, and institutions, such as schools, which generate large amounts of relatively clean PS that could be targeted for recycling programs. This approach is already being used in many schools and other locations in the Northeast.

Section 2

RECOVERABILITY OF RESIDENTIAL PLASTIC RESINS AND PRODUCTS

INTRODUCTION

Section 2 addresses the recoverability of seven resins used in residential consumer applications:

- Polyvinyl Chloride (PVC)
- Polypropylene (PP)
- High Density Polyethylene (HDPE)
- Low Density Polyethylene (LDPE)
- Linear Low Density Polyethylene (LLDPE)
- Polystyrene (PS)
- Polyethylene Terephthalate (PET).

These seven resins are the most commonly used in plastic packaging accounting for over 90% of the plastic packaging market, and are also used significantly in the manufacture of residential durable and non-durable goods, and therefore represent a major opportunity for targeted recovery.

In this section, eleven factors have been identified which affect the recovery of postconsumer plastics. The individual and cumulative impacts of these factors on the potential recovery of resins and products will be assessed. Factors such as quantity available, ease of identification, cross-resin contamination, content contamination, processing capacity, markets, virgin, off-spec and recycled resin, value added product applications, consumer concern, and legislation will be discussed. Next, the recoverability of postconsumer plastics is examined. Finally, conclusions and recommendations will summarize the issues in this section.

Variation in recovery levels exist not only among resin types but also among products in each resin family. Current recovery rates for resins/products for which data are available vary from negligible amounts to mature recovery rates (greater than 30 percent). For example PET beverage bottles are recycled at a 30% rate (calendar year 1990), while

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other PET packaging goes totally unrecovered (See Table 2-1). Conversely, polypropylene bottle recovery is virtually non-existent, as reflected in Table 2-1, while the recovery of PP battery casings reached 88% in Calendar Year 1990. Clearly, at this level, polypropylene battery casings has achieved a relatively mature recovery rate among an infant industry in which the second highest rate is PET beverage bottles at 30%, and the majority of plastic product/resin recovery rates are less than 5%.

Other resins and products commonly recovered include HDPE in products ranging from bottles to base cups. LLDPE/LDPE industrial film recovery is growing primarily in commercial and industrial programs, while PVC and PS residential product recovery are only in their infancy. Interest in the recovery of less commonly recycled resins has reached an all time high, although practical, cost-effective recovery methods, particularly sorting the mixed stream of resins, are still in development. The later discussion of Section 2 will focus on three sub-streams: (1) currently recovered postconsumer plastic, (2) potentially recoverable postconsumer plastic, (3) postconsumer plastic not likely to be recovered in the near future.

Before evaluating these sub-streams, however, we will examine eleven factors that affect plastic recoverability. These factors will then be related to the sub-streams to determine whether they have contributed to or inhibited recovery.

FACTORS AFFECTING RECOVERABILITY

Factors contributing to recoverability include quantity available, ease of identification, cross-resin contamination, content contamination, processing capacity, markets, virgin/off-spec/recycled resin prices, value-added product applications, consumer environmental concern, and legislation. Many interrelationships exist among the above listed factors with the most common denominator being recovery economics.

Quantity Available

For a product to be recoverable there must be incentives for involvement at several levels including local government, those who are responsible for disposal facilities, handlers who will bale or grind the material for market,

RECOVERABILITY OF RESIDENTIAL PLASTIC RESINS AND PRODUCTS

Table 2-1
Estimates of Total U.S. Post-Consumer Plastic Sold and Recycled
in Calendar Years 1989 and 1990
(In Millions of Pounds)

PLASTIC/PRODUCT TYPE	CALENDAR YEAR 1989			CALENDAR YEAR 1990		
	Post-Consumer Plastic Recycled ⁽¹⁾	Plastic Sales ⁽²⁾	% of Plastic Sales Recycled	Post-Consumer Plastic Recycled ⁽¹⁾	Plastic Sales ⁽²⁾	% of Plastic Sales Recycled
PET						
Soft-Drink Bottles	152.44	690	22.09%	224.65	754	29.79%
Custom Bottles	0.13	266	0.05%	2.05	335	0.61%
Other Packaging	0.00	119	0.00%	0.00	136	0.00%
SUBTOTAL: PET Packaging	152.57	1075	14.19%	226.70	1,225	18.51%
PET Non-Packaging ⁽³⁾	55.37	633	8.75%	59.00	664	8.89%
TOTAL PET	207.94	1,708	12.17%	285.70	1,889	15.12%
HDPE						
Milk Bottles	10.08	705	1.43%	49.18	736	6.68%
Other Natural Bottles	1.44	305	0.47%	8.33	340	2.45%
Household Chemical Bottles	3.60	936	0.38%	28.51	926	3.08%
Base Cups	37.84	122	31.02%	49.02	125	39.22%
Film Bags	21.60	635	3.40%	23.55	685	3.44%
Other Packaging ⁽⁴⁾	1.44	1,309	0.11%	1.60	1,392	0.11%
SUBTOTAL: HDPE Packaging	76.00	4,012	1.89%	160.19	4,204	3.81%
HDPE Non-Packaging	0.00	3,238	0.00%	0.00	3,589	0.00%
TOTAL HDPE	76.00	7,250	1.05%	160.19	7,793	2.06%
PVC						
Bottles	0.13	216	0.06%	1.49	223	0.67%
Other Packaging ⁽⁴⁾	0.68	514	0.13%	0.69	539	0.13%
SUBTOTAL: PVC Packaging	0.81	730	0.11%	2.18	762	0.29%
PVC Non-Packaging ⁽⁴⁾	0.04	6,888	0.00%	0.04	7,598	0.00%
TOTAL PVC	0.85	7,618	0.01%	2.22	8,360	0.03%
LDPE/LLDPE						
Film Bags	30.71	2,456	1.25%	34.37	2,683	1.28%
Shrink/Stretch Wrap	51.69	533	9.70%	61.09	552	11.07%
Other Packaging ⁽⁷⁾	24.61	1,545	1.59%	27.71	1,651	1.68%
SUBTOTAL: LDPE/LLDPE Packaging	107.01	4,534	2.36%	123.17	4,886	2.52%
LDPE Non-Packaging	0.00	5,147	0.00%	0.00	5,910	0.00%
TOTAL LDPE/LLDPE	107.01	9,681	1.11%	123.17	10,796	1.14%
PP (Polypropylene)						
Custom Bottles	0.00	129	0.00%	0.42	148	0.28%
Other Packaging ⁽⁸⁾	0.00	1,262	0.00%	0.00	1,353	0.00%
SUBTOTAL: PP Packaging	0.00	1,391	0.00%	0.42	1,501	0.03%
Vehicle Battery Casings ⁽⁹⁾	120.17	151	79.56%	138.35	156	88.69%
Other PP Non-Packaging	0.00	4,623	0.00%	0.00	4,995	0.00%
SUBTOTAL: PP Non-Packaging	120.17	4,774	2.52%	138.35	5,151	2.69%
TOTAL PP	120.17	6,165	1.95%	138.77	6,652	2.09%

Section 2

Table 2-1
Estimates of Total U.S. Post-Consumer Plastic Sold and Recycled
in Calendar Years 1989 and 1990
(In Millions of Pounds)

PLASTIC/PRODUCT TYPE	CALENDAR YEAR 1989			CALENDAR YEAR 1990		
	Post-Consumer Plastic Recycled ⁽¹⁾	Plastic Sales ⁽²⁾	% of Plastic Sales Recycled	Post-Consumer Plastic Recycled ⁽¹⁾	Plastic Sales ⁽²⁾	% of Plastic Sales Recycled
PS (Polystyrene)						
Rigid Packaging	1.20	232	0.52%	1.40	235	0.60%
Foam Food Service	11.62	752	1.55%	14.27	709	2.01%
Other Packaging ⁽³⁾	3.18	711	0.45%	4.07	788	0.52%
SUBTOTAL: PS Packaging	16.00	1,695	0.94%	19.74	1,732	1.14%
PS Non-Packaging ⁽⁴⁾	0.00	3,212	0.00%	0.00	3,209	0.00%
TOTAL PS	16.00	4,907	0.33%	19.74	4,941	0.40%
TOTAL PLASTIC PACKAGING ⁽¹⁰⁾	352.39	13,437	2.62%	532.40	14,310	3.72%
TOTAL PLASTIC NON-PACKAGING	175.58	23,892	0.73%	197.38	26,121	0.76%
TOTAL PLASTIC ⁽¹¹⁾	527.97	37,329	1.41%	729.79	40,431	1.81%
OTHER PLASTIC RESINS ⁽¹²⁾	3.90	15,778	0.02%	10.71	15,684	0.07%
OTHER UNCATEGORIZED RESINS ⁽¹³⁾	22.88	53,107	0.04%	49.76	56,115	0.09%
GRAND TOTAL PLASTICS ⁽¹⁴⁾	554.55	53,107	1.04%	790.26	56,115	1.41%

[1] Based on results of a telephone survey of 162 post-consumer plastic processors conducted from November, 1990 through January, 1991.

[2] Based on data taken from the monthly sales and production reports for domestic resins excluding exports as provided by SPI's Committee on Resin Statistics in the January, 1991 issue of "Modern Plastics." Amounts for Calendar Year 1989 are based on twelve months of actual data; 1990 amounts are based on nine months of actual data and three months of estimated data.

[3] Recycled amounts attributable mostly to X-ray and photographic film.

[4] Recycled amounts attributable to pharmaceutical and cosmetic bottles.

[5] Recycled amounts attributable to film and sheeting.

[6] Recycled amounts attributable to vinyl siding and pipe.

[7] Recycled amounts attributable to containers and lids.

[8] Plastic sales reflect both the amounts of virgin polypropylene sold for use in batteries, as well as an additional 60 million pounds of recycled polypropylene used in battery casing production each year.

[9] Recycled amounts attributable to foam packaging materials.

[10] Amounts reflect values of only the above seven resin types for domestic plastic packaging sales less exports.

[11] Amounts reflect values of only the above seven resin types for total domestic plastic sales less exports.

[12] Amounts reflect total domestic plastic sales, less exports, and total plastic recycled for all other resins, including ABS, polycarbonate, etc.

[13] Amounts include all recycled post-consumer plastics not classified by resin type.

[14] Amounts reflect total post-consumer plastic recycled and total sales of domestic resin, for all resin types, excluding exports.

Source: Modern Plastics, Plastics News, The Council For Solid Waste Solutions

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and reclaimers who are manufacturing goods based on demand for an end-product. A critical mass of material makes it attractive for recovery to a municipality, while quantity is a factor for processors because they must reach economies of scale by maximizing throughput capacity on a single line by maintaining a continuous feed. (The economics of sorting is discussed further in Section 3.) Quantity is equally important to handlers as quantity available determines value. Large volume handlers can often demand a better price from reclaimers and are a more stable market outlet.

In certain instances, the presence of smaller streams of plastic in the waste stream can increase the cost of recovery of other more plentiful resins. When collected and baled with a mixed stream of bottles, PVC has been cited as the cause of processing problems associated with the recovery of PET bottles. One method for PVC to be recovered using today's infrastructure of collection would be a system whereby the processors of PET and HDPE sort out PVC and collectively establish a quantity sufficient for shipment to a PVC processor.

Other recovery methods could be implemented to obtain PVC as a segregated stream. Such solutions could include collection of PVC bottles with existing curbside collection requiring an additional sort. A second solution would be a separate drop-off program for PVC or all 3 through 7 coded plastic, again putting at least part of the onus on municipal collection. Moreover, newly developed automated sorting equipment for PVC has the ability to remove PVC bottles from a stream of PET bottles. Although this equipment may not have the ability to identify 100 percent of all PVC bottles present in a mixed stream, a pre-sort for the removal of PVC bottles during collection followed by an automated sort for the remaining PVC bottles may allow for recovery of both PVC and PET bottle streams.

The August 1991 issue of Modern Plastics discusses a new high intrinsic viscosity PET extrusion grade resin, recyclable and compatible with existing stretch blown PET, but adding the qualities formerly lacking in PET for such applications as large bottles and handle ware products. The new PET grade can even be used with existing PVC equipment for extrusion blowing, yet the material retains the qualities in PET which are superior to PVC such as barrier properties and clarity superiority, no degradation as with PVC, and ease of recycling. There will be difficulties

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in the transition, however, due to the need for PVC users to adapt to the greater difficulty associated with cutting PET which will stretch, exposing of striations or molding defects, and the exacting cooling process. All indications are that these difficulties can be overcome.

Large quantity is certainly a factor that contributes to recoverability of plastic recyclables, however it should not be inferred that just because there is a large quantity of a material that it will be easily recovered. In residential bottles, pigmented HDPE best demonstrates this exception. HDPE milk and PET soft drink bottles are two of the top three bottles produced in terms of weight (736 and 754 million pounds respectively, See Table 2-2). Their recovery is also complemented by universal ease of identification as discussed in the next section. However, as stated previously, the interrelationship of other factors affecting recovery is complex, and in the case of HDPE pigmented bottles, which are actually the largest stream of bottles available (926 million pounds produced), other factors overshadow quantity, effectively hindering recovery. In this case, content contamination associated with HDPE chemical bottles and confusion over which pigmented HDPE bottles are recoverable have depressed recovery.

Table 2-2
Primary U.S. Residential Plastic End-Products
Listed by Resin Type
(Million Pounds)

Plastic/Product Type	1989 Sales	1990 Sales
PET		
Soft-Drink Bottles	690	754
Custom Bottles	266	335
HDPE		
Milk Bottles	705	736
Other Natural Bottles	305	340
Household Chemical Bottles	936	926
PVC		
All Bottles	216	223
PP		
Custom Bottles	129	148

Source: Modern Plastics 1990, 1991

Closely related to quantity is recovery/solid waste legislation that has been a key factor in establishing a critical mass of material for recovery. This factor will be discussed in greater detail later in this section.

Ease of Identification

Ease of identification is a factor of recoverability, which is closely related to quantity. There is no cost-effective and simple method for identifying polymer type. Product and name brand recognition are more easily understood by consumers, whose participation is paramount to recovery, and to plastic handlers, who are required to upgrade the material for market.

The Society of the Plastics Industry ("SPI") coding system has been widely implemented to identify polymers but is confusing to consumers. One reason for the ineffectiveness of this system is that some bottles consist of more than one polymer. For example, certain PET soft drink bottles have PS closures or PVC cap liners. Additionally, differences in fabrication technology of polymer types can make the same resin self-contaminating (blow-molded vs. injection-molded HDPE containers, both SPI coded "2"), and general misinterpretation of the meaning of the chasing arrows symbol has rendered the system less than effective.

By implementing the SPI number concept, some reclaimers have contributed to the confusion by leaping back and forth with acceptable specifications. For instance, the City of Tampa, Florida initially distributed public education materials for their plastic drop-off program soliciting all 1's and 2's. Due to excessive contamination (primarily as a result of the public's inability to effectively differentiate between the various codes, and their treatment of all plastics as recyclable) the City's plastic reclaimer (formerly the Plastic Recycling Alliance, a joint venture company formed by Waste Management and DuPont) changed their specifications to include only milk, soft drink, water, and laundry bottles. The City has since incurred the expense of re-educating the public.

Generally, PET processors would like to ensure quality by accepting only soft drink bottles from postconsumer sources rather than all other PET bottles due in part to problems with cross-contamination, content contamination, and look-alike bottles as outlined below. In direct contrast, the National Association for Plastic Container Recovery ("NAPCOR") is

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actively promoting the collection of all PET containers with their "Look Out for Number One" campaign. Milk and soft drink bottles have universal recognition. The safer route is to limit collection to milk and soft drink bottles. Programs should consider collecting other PET and/or HDPE bottles only after a secure outlet is identified for these custom PET bottles and pigmented/injection grade HDPE containers. As discussed later in this report, a combination of solutions may be required in some circumstances. Potential short-term solutions, such as training collectors and sorters (assumes little turnover), educating program participants, or adding attendants at drop sites, would not be recommended long-term "solutions" as they would add to program costs but not eliminate product contamination, merely perpetuate an ineffective resin identification system. Alternatively, automated sorting may be a cost effective long-term answer to resin identification.

Yet, until automated sorting becomes available to more cost effectively sort a mixed stream of plastic, collection efforts should focus on educating the public on certain physical characteristics of the material to be collected such as the type of product (laundry bottles) or the products' shape (all narrow neck bottles) to ensure marketable material.

Product based identification is more effective than number code identification. This conclusion is based on field testing of instructions, signage, and literature for a drop-off program in the City of Tampa. Number code definition led to 29% contamination, while product-based definitions generated only 8% contamination. Also gradual addition of polymers/products to programs will lessen the hindrance of confusing numbering that tends to result in collection of plastics which are not acceptable to processors at this time.

Cross-Contamination

The issue of product cross-contamination has largely focused to date on the recovery of postconsumer plastic bottles, although it is likely that cross-contamination will also play a role in the recovery of residential durables and non-durables in the future.

Cross-contamination occurs when a bottle is made from more than one polymer, or when bottles of different polymers are ground together. The most severe problem is the contamination of PET by PVC, since small amounts of PVC can ruin whole batches of PET resin. Products made of

the same resin, but fabricated differently also present a serious problem involving incompatible melt indexes. Less serious is contamination of HDPE by PP. This problem can be overcome through designing for recycling (incorporating compatible resins into mixed-resin products), or through automated sorting technologies which are discussed in Section 3. Although HDPE and PP have similar densities and cannot be separated by traditional sink/float methods, PP contamination in small quantities (5 to 10 percent by weight) will not render recovered HDPE useless, although it may lower the value of the material if the contamination is at the high end of this scale. As long as the majority of PP caps are removed from HDPE bottles (PP spouts on HDPE laundry bottles have been known to be left on without significant degradation of the material), and only few occasions of human error allow whole PP bottles to slip through an HDPE line, the quality of HDPE recovered is not drastically reduced due to the presence of PP.

A more serious problem occurs with PET/PVC cross-contamination. Custom PET bottles such as Ocean Spray and Gatorade with PVC cap liners, as well as PET look-alikes such as PVC Wesson Oil bottles have caused large amounts of PET beverage bottles to go unrecovered. Loads of PET bottles mixed with small quantities of PVC bottles are commonly found among municipal suppliers who lack the technical expertise to recognize contamination. Generally, bottle bill material is a pure stream, as the handlers are more familiar with product identification and the deposit does not apply to bottles like Wesson since they do not contain a beverage. Contrary to the widely held opinion expressed by many handlers to Beck during various surveying projects, moderate training of full-time sorters (in contrast to day labor) as to how to correctly identify these PVC containers could dramatically improve the recovery of the plastic bottle stream. In fact, the consultant worked on a project in South Florida (Miami Recycling) where this improvement did occur.

A more subtle but related problem occurs with aluminum and PP caps on PET bottles, PP and paper labels, and HDPE base cups. The PP in soft drink bottles is generally blended with the HDPE base cups when the bottle is ground, yielding a lower quality resin. One solution is for manufacturers to design for recyclability with one polymer type, such as a one piece bottle, or a maximum of two polymers with opposite densities so they can be easily separated and both recovered. For example, using traditional sink/float technique the PET body of the soft drink bottle will

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sink when granulated and put into a wash system, while the HDPE base cup will float to the top of the tank and can be skimmed off.

Care must be taken however not to promote production of a bottle with the same resin but different fabrication technologies. This could cause incompatible melt indices (e.g., blow-molded vs. injection-molded HDPE) or color contamination (since a higher value is placed on clear PET, an inked PET label used on a clear bottle would drastically lower the material's value). Similarly, clear PET bottle material would be de-valued if green and black base cups were made from PET due to the limited market in both bottle and fiber applications for colored polyester. Rather than making a soft drink bottle whose base cup and cap are PET, the ideal bottle would be one piece, like Coca Cola's "big foot" with an aluminum cap (no PET/PET incompatibility, or PP cap/HDPE cup incompatibility).

Film plastics also suffer cross-contamination when recovered in a mixed stream. Bags from retail stores may be either HDPE, as in the more "crinkly" K-Mart bags, or LDPE/LLDPE as found in some grocery stores. The mix of polymers, as well as inks and content contamination make recovery of a pure resin more difficult.

Similar problems can be expected as the recovery of postconsumer plastic extends into the collection and processing of residential durable and non-durable goods. Computer components, auto parts, and household items such as telephones and desk top items will likely need to be designed for recyclability or face low value markets (if markets are available) for the recovered plastic.

Content Contamination

Content Contamination in Bottles

Content contamination of plastic bottles poses four problems which are barriers to recovery: (1) contents may leave residues which cannot be removed; (2) residues may leak onto clean material or pollute soil or water; (3) contents may mix and create dangerous chemical reactions; or (4) medical waste in bottles may pose safety hazards to MRF workers. Moreover, increasing reliance on dirty MRF's that pull recyclables out of mixed garbage prior to incineration, and MSW composting will exacerbate all of the foregoing problems.

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Educating the public about the importance of washing out problem residues, about types of containers which are acceptable in a collection program, and about the proper disposal of home medical wastes are the most effective ways of overcoming these problems.

Content contamination leads to two processing problems that make recovery of all resins difficult. First, residue from the packages' original contents may penetrate the plastic to the point it cannot be cleaned or may leave an odor that cannot be eliminated and second, residue left in the container, when mixed with residue from other containers, may cause undesirable chemical reactions or individually may cause undesirable leakage problems at storage yards causing ground contamination.

Oil residue is a particular concern with ground contamination. There is more than one system for removing oil residue from wastewater in processing. However, processors are concerned both about oil leakage onto storage sites and the spread of oil contamination to other, previously easy to clean materials.

Chemical reactors are also a concern. A chemical reaction can occur simply from the mixing of bleach with ammonia residue which produces ammonium chloride and small amounts of chloride gas. One company, that operated a mixed plastic pilot plant in Allentown, Pennsylvania had to shut down for a half day when employees got sick due to fumes from the various chemical mixes. Workers compensation issues become a concern as well because the combination of certain bottle residues can threaten worker safety.

Again, products that are not available in large quantities, and additionally have to be handled as a separate stream due to quality and safety concerns are less recoverable. Recyclers of bottles with non-threatening residue (lactic acid/syrup/detergent) are discouraging the acceptance of bottles requiring special handling. The specifications for Quantum's new recycling venture would reject bottles having contained antifreeze, oil, transmission fluid, pesticide or herbicide. Specifications for Phillips 66's purchasing requirements read that no "brown bottles" (indicating use as an insecticide) are acceptable.

More and more companies are issuing stricter specifications which could inhibit recovery. One new restriction is limitations and penalties based on the amount of free flowing liquids in the containers. If companies like

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Quantum and Phillips are not willing or able to sort, then another infrastructure to bring back content contaminated bottles in a separate stream must be developed.

Wastewater treatment is another reason limitations have been set on content contamination. Generally wastewater in plastics recycling plants enters the system from two points, overflow from the wash water recycle tank, and at the point where all flow water is collected in drains. Ultimately waste water is routed to a holding tank where solids are screened off using a vibratory screen, and emulsified oil and grease are removed from the top of the tank. Introducing unknown chemical residue to this system could jeopardize the amount of waste recovery, and could cause inconsistencies in pH content prior to discharge into sanitary sewers, or even create a liquid that could not be discharged into sanitary sewer systems.

Another severe contamination issue arises out of home use medical waste. The National Diabetics Association ("NDA") recommend disposing of syringes in plastic bottles, placing the cap back on and putting the container in the garbage. Many of these bottles with medical waste are showing up at recycling plants causing concern for employee health risks. There is also legitimate concern for handling and transporting materials that most recyclers are not permitted to handle, additional disposal costs of sensitive materials, and employee turnover due to concerns associated with needle contact. The NDA has produced literature and written articles in trade journals emphasizing that bottles used for "proper" disposal of syringes and other home use medical waste not be placed in recycling bins, but in the garbage. However, NDA continues to recommend the utilization of plastic bottles for disposal as "proper."

This will continue to contribute to the recycling problem even if 100% of all users placed their medical contaminated bottles in the trash rather than the recycling bin. The reason for this is the increased number of mixed waste processing facilities, dirty MRF's, composting, or other volume reduction methods. These systems of gathering recyclables will continue to be threatened by the medical waste problem. The number of these facilities is growing and there is no way of controlling medical contamination since most of these systems have mechanized separation, and yield a dirtier bottle that is not as easily seen through to detect content contamination.

Content Contamination in Film

Commercially collected film for recycling comes in a variety of forms from a variety of sources. HDPE and LDPE film bags are being collected in grocery stores; PET x-ray film is being collected from hospitals and clinics; and film garment bags are being collected at a few dry cleaning stores. However, in terms of total volume recovered, film recycling is very limited at the present time. As Table 2-1 show, slightly more than three percent of the HDPE and LDPE/LLDPE film bags and shrink wrap were recycled in 1990.

Content contamination of film includes residue left in grocery bags and chemical residue resulting from the extraction of silver from x-ray film. Packaging film is often contaminated with food waste, discouraging collection of this material. In the short-term, the best solution to these problems is to educate consumers and other film users about the importance of keeping film clean. The development of film cleaning technologies may offer a long-term solution.

According to the article "Recycling Plastic Grocery Bags" Biocycle, June, 1990, the contaminants in grocery bags include paper lottery tickets and biodegradable plastic bags. These contaminants, along with food waste makes grocery sack recovery difficult. Some stores, such as Shoprite Supermarkets and Pathmark Stores, have chosen to offer a one- or two-cent rebate to customers using reusable bags, instead of collecting plastic bags.

PET x-ray film from post-industrial and commercial waste sources is highly recoverable and has a relatively high value, because of its silver content. Removing the silver can contaminate the film, making the film unacceptable for remanufacture. Most silver reclaimers do not even consider the film as a recoverable material. The silver is extracted from the film using a sodium cyanide or calcium cyanide solution. The cyanide in the plastic, which can give off noxious fumes, cannot be removed through washing. This renders the cyanide-treated film useless for recycling. An alternative process, using enzyme-based solutions, can also be used to extract the silver. This alternative process will not contaminate the remaining plastic film. A education program for x-ray film processors is recommended to increase the recoverability of PET film. Wellman, Inc. utilizes some PET x-ray film to make polyester fibers, but the incoming

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loads are subjected to laboratory analysis to be sure there is no cyanide residue present. Such analysis is an obvious barrier to high levels of recovery.

Content contamination and high collection costs have kept the amount of film being collected relatively small. Only one U.S. Recycling company, Rhino-X, grinds, washes, and processes mixed postconsumer films back into t-shirt bag material. Boston-based Carlisle Plastics controls Rhino-X which has been operating for one year with facilities in Texas and California. Some bags collected by bag distributors go back into their own bags, but the converting process is labor-intensive and the scale is small.

Four new film recycling plants are starting up targeting higher value in-house markets and film markets. The plants include Union Carbide in Piscataway, New Jersey; Petoskey Plastic, Inc. in Petoskey, Michigan; North American Plastics Recycling Corporation in Fort Edward, New York; and South Eastern Plastics Recycling, Inc. in Mobile, Alabama. The sources of the plants will be polyethylene film from bags used for the collection of recyclables, garment bags from dry cleaners, and grocery sacks. Each plant will use different technologies to solve contamination problems.

These facilities for recovery mixed plastic film should soon provide data on the feasibility and potential growth of such enterprises. For example, the Petoskey plant is addressing the contamination of film by food and paper with a technology from Fabrica Bondoneses Machine in Italy. This process is said to clean without water, using a continuous hot melt filtration in the extruder which effectively removes grass, sawdust, paper, and even non-compatible resins such as PVC. Until technologies such as this are proven, processors and end-users must continue to rely on public education programs to address content contamination.

To minimize content contamination, the public must be informed about the importance of thoroughly draining and cleaning targeted plastics. Handling of hazardous materials, of course, should conform to Haz-Mat programs. Also, a solution to the disposal of home-use medical waste must be developed by doctors and medical associations, and effectively communicated to consumers.

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The appropriate agencies are taking a role in defining the method of disposal for home-use medical waste, including the EPA, the National Diabetics Association, and other medical associations. However, the EPA should take the lead in re-examining the recommendations in light of the growth in mixed waste processing facilities, and other recycling methods in which these contaminated bottles tend to surface.

Processing Capacity

Although existing postconsumer processing capacity appears adequate for the near term, it is not likely that it will meet the anticipated need for new processing capacity, nor are many of the processing facilities strategically located near collection programs and end-markets to allow for cost-effective reprocessing of postconsumer plastic. For example, large amounts of PET from California have been shipped as far as South Carolina to Wellman's large PET processing center, at negative net value, due to a lack of closer reclaimer and end-market.

Table 2-3 shows the current nationally installed plastics processing capacity by resin type of the calendar year 1990. This capacity is growing, not only in the Northeast, but in the nation as a whole. Entrepreneurs, as well as major corporations, are launching new recycling ventures.

Resin Production and Price Cycles

Growth in the number of non-traditional recyclers, such as large virgin producers and end-users; entering the plastic reclamation industry is very encouraging. Their participation will be critical to negate or at least reduce the impact of the typical virgin resin price cycle that reduces the value of postconsumer resins. Several companies including recyclers such as Wellman and Partek as well as resin companies such as Quantum and Phillips have stated that during periods when resin demand exceeds supply, the chemical companies will respond by building huge new petrochemical plants (oversized to gain market share as well as to maximize throughput) in many instances costing hundreds of millions of dollars and taking several years to bring on-line. Usually more than one of the larger chemical companies will set out to fill the void in supply to protect market share, resulting in more than one oversized, expensive

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Table 2-3
U.S. Installed Plastic Processing Capacity
Calendar Year 1990 ^[1]
(Millions of Pounds per Year)

Resin Type	Post-Consumer ^[2]	Industrial Scrap ^[3]
PET	394.8	113.1
HDPE	291.0	397.8
PVC	1.3	133.6
LDPE/LLDPE	135.3	431.5
PP	158.4	90.1
PS	19.4	58.9
All Others Resins	28.6	63.4
Non-Classified Capacity ^[4]	270.6	1,959.7
TOTAL	1,299.4	3,248.1

^[1] The values shown are estimates reported by plastic recycling firms carrying out the last value-added process prior to end-product manufacturing (usually pelletizing or washing/cleaning).

^[2] A considerable portion of the post-consumer plastic processing plant capacity is currently incapable of cost-effectively processing post-consumer plastic due to a lack of sorting and/or washing/cleaning equipment.

^[3] The values shown for industrial scrap plastic processing plant capacity are based on information provided by post-consumer plastic reclaimers and are in no way an attempt to comprehensively estimate the total availability of industrial scrap processing plant capacity in 1990. The information obtained for this table was done so through telephone interviews on behalf of The Council For Solid Waste Solutions.

^[4] Non-classified capacity refers to processing plants capable of processing a variety of resins depending on the availability of profitable end-markets. An additional 2.3 billion pounds of plant capacity not reflected in Table 2-3 was reported to be capable of processing either post-consumer or industrial scrap plastic.

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plant being built. When these plants come on line, usually in rapid order, the market situation changes drastically from high demand, to over-supply and excess capacity. Because companies' capital has already been committed, their new plants continue to be brought on line despite the glut.

Collectively, these companies begin to turn out virgin resin in quantities which far exceed the original demand that triggered the cycle. The glut leads to low value virgin resin leading to greater use of virgin rather than recycled resin. Over time, the price of virgin will gradually climb as a result of increased demand. Yet, rather than stabilizing, tight market supply conditions will produce high resin prices for a long enough period of time to begin the building cycle all over again.

To end this continuing cycle, a more balanced approach must be taken to the development of both virgin and recycled resin facilities, with the emphasis on developing plastics recycling facilities that can absorb a greater percent of the increased resin demand over time. This solution should soften the impact of the typical cycle as the development time for a postconsumer recycling plant is much shorter, as short as six months, enabling an immediate response to demand. Recycling plants are much smaller and, therefore, will not create the giant swings in over-capacity associated with new petrochemical plants. However, virgin resins, having inherent higher qualities, will always dominate certain markets such as food grade and medical applications.

Several companies have announced their intention to build recycling plants. Major corporations going forward with recovery plants include Quantum Chemical Corporation, Phillips 66, and Union Carbide. Most of these facilities are planned to process at least 20 million pounds per year of recycled material. Addressing less commonly recycled plastics will be the National Polystyrene Recycling Company ("NPRC") for polystyrene, Occidental Chemical Company for PVC bottles, Mobil for LLDPE and LDPE and Exxon for Polypropylene. These same companies continue to build large virgin plants. The minimum size of an economically feasible virgin resin plant is 200 million pounds, although the norm is to build at least a 250 million pounds of capacity. The recent expansion of Phillips 66 included two 300 million pound capacity plants to produce virgin HDPE. If the above companies' new recycling ventures are successful, they may respond differently during the next cycle of high demand. A lack of facilities for less recoverable plastic persists due primarily to a lack

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of affordable large quantities of these materials and end market availability.

Based on free market forces, demand for PCR will be based on its price competitiveness to virgin resin (as discussed later in this section). Therefore, it will be necessary to develop recovery methods for postconsumer plastic that will make PCR an attractive alternative to virgin. If PCR continues to be priced out of the market, demand-oriented legislative action in the form of content legislation (as compared to supply-oriented such as recovery goals) may be required in order to ensure that postconsumer plastic is recycled.

Reclaiming Markets

Northeast Reclaiming Markets

The Council For Solid Waste Solutions' survey of plastic reclaimers shows at least 43 processing plants in the Northeast area (Table 2-4) for recycling various grades of plastic and 166 reclaimers nationally. The majority of these facilities are recycling only common grades of PET and HDPE at this time. However, a number of mixed grade processors, making artificial lumber/concrete products, serve as an interim solution for mixed plastics.

Due to a weakening virgin resin market as discussed above, many postconsumer plastic handlers and reclaimers have required that plastic be separated prior to delivery and are imposing more stringent quality requirements on incoming feedstock to lower the costs of reclaiming this material and make it more price competitive with its virgin counterpart. As mentioned earlier, The Plastic Recycling Alliance accepts only PET soft drink and HDPE milk/juice/ water and laundry bottles as compared to all 1's and 2's. Similarly, Graham Recycling Company, a reclaimer located in York, Pennsylvania, tried to accept a wider array of mixed plastic bottles shortly after opening, but has since narrowed its definition of acceptable plastic bottles and requests that the material be segregated prior to baling.

The number of reclaimers in the northeast appears adequate to handle the current flow of PCR, and can probably increase capacity to handle

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Table 2-4
Post-Consumer & Industrial Plastic Reclaimers in the Northeast

State	Company Name	City Name
Connecticut	Hafner Industries, Inc.	New Haven
	Plastic Recovery Corporation	New Haven
Massachusetts	Environmental Resin Bags Ltd.	Stow
	Metropolitan Processed Materials	Somerville
	wTe Recycling, Inc.	Bedford
	Come Play With Me Products	Worcester
New Hampshire	C.C.C., Inc.	Nashua
	EDA Plastics	Keene
New Jersey	Day Products	Bridgeport
	P. A. Plastics and Trading	Plainfield
	NPRC/CR Inc.	Bridgeport
	Plastic Sales and Export Co., Inc.	Clifton
	Pure Tech International, Inc.	Pinebrook
	Wheaton Plastic Recycling	Millville
New York	Boulder Consultants, Ltd.	New York
	Fox Run Recycling	Seneca Falls
	MG Chemical Co., Inc.	New York
	National Waste Technologies	Ronkonkoma
	NICON Plastics, Inc.	Long Island City
	North American Plastic Recycling Corp.	Ft. Edward
	Ontario Recycling Corp.	Rochester
	Plastic Recyclers, Inc.	Bay Shore
	Plastics and Metals Recycling	Blodgett Mills
	Polymerix/Trimax	Ronkonkoma
	Polystyrene Recycling, Inc.	Brooklyn
	Recoverable Resources Boro Bronx	Bronx
	Shuman Plastics	Depew
	Tulip Corporation	Niagara Falls
	wTe Recycling/Star	Albany
Rhode Island	Rhode Island Resource Recycling	Lincoln
Vermont	Casella Waste Management	Rutland
	Vermont Rep. Industries, Inc.	St. Albans
Maine	None	
Delaware	Dupont	Wilmington
Pennsylvania	Dart Container Corp.	Leola
	Environmental Plastics	Washington
	Exide Corporation	Reading
	George Woloch Company	Allentown
	Graham Recycling	York
	Nicos Polymer/Grinding	Easton
	Occidental Chemical	Berwyn
	Plastic Recycling Alliance	Philadelphia
	Polycycle	Scranton
	Riverhead Milling, Inc.	Philadelphia

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increased flow. However, in this period of weak demand, the critical issue is not the number of handlers and reclaimers, but the location of end-markets and their contractual arrangement with reclaimers. Reclaimers who have contracts with end-markets can move material. Without such contracts, reclaimers will have no outlet for their materials, no matter where they are located.

Markets In Other U.S. Regions/Export

There are at least 400 handlers and reclaimers in other regions of the U.S. These markets, along with those in Canada and other export markets, may have an indirect effect on recovery of materials in the Northeast. If these markets were experiencing high demand, therefore higher value, this value could put pressure on northeast markets. However, generally material going to a more distant market would lose value due to the extra shipping costs, so the price would not likely be raised.

The distant markets in the U.S. may in fact be handling material that is generated in the northeast. There has been a shift, however, from the development of facilities to handle material procured nationally, such as Wellman's 200 million pound plant in South Carolina, to smaller plants designed to handle regional material, such as the Graham, Quantum, and Phillips plants. The risk in utilizing, or becoming dependent on distant U.S. or foreign markets, is that northeast material suppliers will likely be cut off first if more material becomes available in the area of the plant. For example, if the Carolinas, Georgia, Tennessee and Alabama became very active in recycling, the lower transportation costs due to their proximity to the plant would probably coax Wellman to buy within the southeast region only, if that supply could satisfy their appetite. California has relied heavily on export markets and found those markets for recycled raw materials to be unstable. Export market instability is as likely for recycled pulp or plastics as it is for chemicals or oil.

Market Price of Virgin/Off-Spec/Recycled Resins

Market prices dictate consumption of recycled plastics in most cases. Virgin prices suffer greatly when overcapacity exists, and consequently dramatically affect the value of PCR. The present recession combined with overcapacity has greatly reduced market prices. Table 2-5 reflects the historical prices and current value for common recycled resins.

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Off-spec resin (virgin resin which, for several reasons, does not meet the exact quality specifications for which it was originally intended) also tends to cut into the value of recycled resin, since off-spec resin is preferred to PCR when the price differential between the two resins narrows. Collection, sorting, and transportation costs of PCR are relatively fixed at all levels including municipality, handler and reclaimer. To continue postconsumer plastics recovery over the long term, PCR must be priced sufficiently high enough to cover these costs and provide a reasonable return. As mentioned previously, this may include the need for legislative assistance in the form of artificial demand by requiring content, and/or by reducing handler costs by passing through advance disposal fees ("ADF").

Advance disposal fees are a relatively low charge (i.e., 1-2 cents on containers, 1 dollar on automobile tires) on consumer goods, collected at the point of purchase, and intended to recognize a product's contribution to the overall solid waste problem. Funds collected may be used for a variety of solid waste purposes, but primarily to further proper disposal/recycling infrastructures. As proposed in this section a portion of the funds collected from the ADF could be returned to handlers to subsidize their role in the recycling loop.

A 1988 law designates that Florida will implement a one cent advance disposal fee on all containers of glass, plastic, aluminum, and other metals as well as aseptic drink packages, plastic coated paper cartons and other container types to ensure a level playing field among competing products. Once a product exceeds a 50% recycling rate in Florida it will not be subjected to the fee. Currently, conceptual rule making is underway with regard to carrying out the ADF as written in the Florida law, and it appears that funds collected will exceed 100 million dollars, a portion of which will be used for market development, litter control, municipal grant funds to support recycling collection, and potentially a rebate in tax bills and solid waste assessment charges.

Ideally, more economical sorting and efficient collection systems will reduce the costs of PCR. This along with industry commitment to purchasing PCR for its environmental benefit despite potentially lower virgin pricing will resolve the issue over time.

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Table 2-5
Historical Pricing of Commonly Recycled Resins
(average annual value in cents/lb)

Plastic Type	1988 ^[1]	1989 ^[1]	1990 ^[1]	1991 ^[2]
PET (clear)	59.16	63.33	56.30	36.00
HDPE (natural)	41.00	41.00	35.30	31.90
PVC	58.58	61.08	58.00	NA ^[3]

Sources: ^[1] Reclaimer data reported through interviews.

^[2] Plastics News

^[3] Not Available

Consumers must also create demand for recycled resin by buying products in packaging with recycled content or that is recyclable, or both. Interviews with consumer product manufacturer, Procter & Gamble, have indicated that products sold in such packaging can cause a loss in market share if a similar product from another manufacturer is offered at a lower cost, due to less expensive packaging made from virgin resin. However, if consumers don't support more costly recycled packaging, it is questionable whether large corporations will integrate PCR into their packaging. Generic/store brand (such as CVS or Eckerd) and small product lines not committed to using containers with recycled content have had cheaper manufacturing costs to pass on to consumers, and could potentially gain market share by being less environmentally supportive and opting for virgin resin packaging which makes the entire product less expensive.

Again, this may require that legislative action be taken to assure that PCR is used not only in packaging, but also durable and non-durable consumer goods. It will be important to provide an "even playing field", assurance that similar packages of different resins, or commodity types, are given the same, relative, or proportional content or other legislative mandates when implementing such demand-side legislation in order that all plastic end-users are treated equitably.

Legislative initiatives to mandate PCR use could create a demand for PCR, offsetting the impact of low virgin pricing.

Value-Added End-Product Applications

Historically, recycled resins have been used in products requiring less than the highest quality resin such as piping, flower pots, middle bottle layers and strapping. These applications which can tolerate color contamination are the most widely held uses for PCR since color separation of the same polymer type has not been perfected. A key to creating higher value added end markets for PCR is the development of color separated resins which would allow for the creation of significantly more end-use applications since the market for dark, black, or mixed color shades is very limited. Color separation would also advance closed loop bottle recycling.

Some non-bottle applications have been very successful and the cornerstone of past recycling efforts. End markets for PET such as fiberfill and carpeting continue to absorb large amounts of reclaimed material. For HDPE, drain tile producers generally have paid more to reclaimers for resin than have bottle producers, primarily because the reclaimed material can only be used in middle layers of bottles. The lowest value end products have resulted from mixed plastic processing and include the line of substitute lumber/concrete products. Recovery will be enhanced by the development of more value-added end-markets for PCR since increased revenue to offset collection costs has been extremely important to municipal collection programs.

Additionally, recovery would be assisted by the creation of a variety of markets to compensate for the economic downturns experienced in several industries, such as the lull in polyester fiber prices a year ago. Lines could be switched over to make bottle grade resins, or some other value added end-product. Because there must be a consistent affordable supply before end-product manufacturers will commit to using PCR, many of the less commonly recovered plastics have yet to be tested in many product applications. For example, there are a number of high value, non-bottle PVC products that could potentially be supplemented with recycled bottle resin, but since the quantity of PVC bottles available is negligible there has been no substantial demonstration of end-product use. End-product applications for PCR will be discussed in greater detail in Section 4.

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Consumer Environmental Concern

Survey after survey suggests that the public is increasingly concerned with the state of the environment. For example, a recent poll performed by Environmental Research, Inc. of Princeton, NJ found that half of all respondents had boycotted a plastic product within the last month due to their belief that plastic was not recyclable.

Public opinion also drives legislative action. Consumer environmental sentiment will continue to play a leading role in determining the future recovery rates of postconsumer plastic. But will public concern translate into changes in purchasing patterns?

A recent poll performed for the Wall Street Journal stated that although the public verbally backed the recovery of recyclables such as plastic, a much smaller number of individuals translated this urgency into purchases at the local supermarket or department store. Many of those surveyed stated that they would be willing to pay extra for such goods if it were legislated to affect the public as a whole. This may signal the need for legislation requiring content or advance disposal fees, at least for a period of time, in order to establish the use of PCR.

Legislation

Local, state, and federal legislation mandating solid waste reduction or, more specifically, plastics recycling have been a great contributing factor to postconsumer plastics recycling to date. Between 1979 and 1983 state beverage container deposit legislation was implemented in nine states resulting in the availability of a critical mass of PET soft drink bottles for recycling. A few companies responded to this source of inexpensive raw material for fiber applications. Although the deposit bills were the primary mechanism responsible for the recovery of over 190 million pounds of plastic soft drink bottles during Calendar Year 1990, state legislation requiring programs for curbside or other residential collection programs also increased recovery of plastic.

Because such legislation varies from state to state in the specificity and intensity of the mandate as well as in the level of negative incentive, some states have been more successful at addressing the plastic waste stream than others. For example, some legislation specifies that at a minimum paper, glass, aluminum and plastic must be addressed, while other legislation offers a "menu" of recyclables from which a community must address

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a certain number of items but may choose to leave out plastic. Even less stringent legislation simply sets a waste reduction goal, expressing that recycling is an obvious and desirable way to reach that goal, although not specifically mandating that certain items be targeted for recycling or banned from traditional disposal.

In response to the State of Florida's 1988 Solid Waste Management Act, over 150 curbside recycling programs were implemented, many of which collect plastic soft drink, milk/water, and laundry bottles. Florida's Solid Waste Act should result in the recovery of a substantial quantity of postconsumer plastic in the future. The Act requires that a majority of the State's plastic beverage containers be recycled by 1992, with financial penalties aimed at both industry and local government for failure to meet the goal.

At least 34 states have passed waste stream recycling goals ranging from 20 to 60 percent, 14 of which have deadlines of no later than 1995. In the Northeast, nine states have legislated waste recycling goals. Legislative initiatives will continue to play a key role in determining the level of postconsumer plastic recycling in the future. The role of legislation however must go beyond collection to include end-market development if recycling programs are to be successful. Public procurement policies mandating the purchase of recycled plastic products are an essential legislative step toward absorbing significant supplies of postconsumer plastics. This step could be taken at the local, state, and federal levels of government. Government purchasing has been cited as accounting for approximately one third of the U.S. Gross Domestic Product. Alternatively, content legislation for plastic in containers as well as film of over one mil thickness could be considered on a national basis with a minimum target of recycled content of 10 percent by 1993, and 25 percent by 1995. The passage of such legislation should take into consideration technical barriers to incorporating recycled content beyond certain levels and the current use of industrial scrap in such applications. In other words, content legislation should not reduce the current recovery of industrial scrap plastic.

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RECOVERY OF POSTCONSUMER PLASTIC

The following discussion focuses on the current recovery rates of major resins/products, on the resins/products with good potential for higher recovery rates, and on those resins/products which are not likely to achieve high recovery rates. Table 2-6 summarizes the recovery rates of these resins/products in 1990.

Table 2-6
Recovery Rates of Selected Resins/Products in 1990

RESIN/PRODUCT	1990 SALES ⁽¹⁾	AMOUNT RECOVERED ⁽¹⁾	PERCENT RECOVERED
PET Soda Bottles	754	224.65	29.8
HDPE Base Cups	125	49.02	39.2
HDPE Milk/ Water Jugs	1,076	57.51	5.3
HDPE Chemical Bottles	926	28.51	3.1
HDPE Film	685	23.55	3.4
LDPE/LLDPE Film	2,683	43.37	1.3
PVC Bottles	223	1.49	0.7
PP Bottles	148	0.42	0.3
PP Battery Casing	156	135.35	88.7
PS Foam Food Service	709	14.27	2.0
TOTAL	7,485	578.34	7.73

(1) millions of pounds

Source: Modern Plastics, 1991; Council for Solid Waste

Currently Recovered Plastic

Several factors have had a significant impact on the recovery of postconsumer plastic and are expected to influence its recovery in the future. The initial forces were ease of identification for PET soft drink bottles and milk jugs and mandatory recycling legislation. More recently, recycling has been driven by the amount of material available, end-market availability, and public sentiment, which in turn drives legislation. The recovery rates for the seven postconsumer resins discussed in the report during 1989 and 1990 are shown in Table 2-1.

Of the seven resins, PET had the highest rate of recovery. Approximately 227 million pounds of PET packaging were estimated to have been recycled in 1990, compared to 153 million pounds in 1989 for an annual increase of 48%. Soft-drink bottles contributed almost exclusively to achieving PET's 18.5 percent postconsumer plastic packaging recycling rate for 1990 (see Table 2-1).

HDPE postconsumer packaging recycling more than doubled during 1990 with over 160 million pounds of postconsumer HDPE packaging recycled. Approximately 76 million pounds of the postconsumer HDPE packaging was estimated to have been recycled in 1989. Postconsumer HDPE packaging recovered consisted primarily of milk and water bottles, pigmented consumer bottles, soft-drink bottle base cups, and film bags. Postconsumer HDPE packaging was recycled at a rate of approximately 4 percent in 1990 as compared to approximately 2 percent in 1989 as reflected in Table 2-1.

Polyvinyl Chloride postconsumer packaging consisting primarily of food, pharmaceutical, and cosmetic bottles and film was recycled at only minor rates during 1989 and 1990. Approximately 2 million pounds of postconsumer PVC packaging are estimated to have been recycled in 1990, up from 800,000 pounds recovered in 1989. Postconsumer PVC packaging recycling consisted primarily of the recovery of bottles and film. Postconsumer PVC packaging was recycled at a rate of approximately 0.3 percent in 1990 as compared to approximately 0.1 percent in 1989 as reflected in Table 2-1.

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Postconsumer LDPE/LLDPE packaging recycling surpassed 123 million pounds in 1990, a 15 percent increase over the 1989 level of 107 million pounds recycled. These packaging resins were recovered in products such as film bags, stretch wrap, and lids. LDPE packaging was recovered at a rate of approximately 2.5 percent in 1990.

Postconsumer PP packaging recovery during 1990 was estimated to have been 420,000 pounds, or less than 0.1 percent of all PP postconsumer packaging produced domestically in 1990. No PP postconsumer packaging recovery was reported to have taken place during 1989. Although PP postconsumer packaging recycling was relatively low during the study period, it is anticipated that PP film, which accounts for approximately 90 percent of all PP packaging will contribute to PP's recycling rate in 1991 based on at least one recent announcement by Exxon for start up of a PP film recycling facility in South Carolina during 1991. It is also important to note that the product with the highest recovery rate in 1990 was the PP battery casing.

Postconsumer PS packaging consisting primarily of foam food service and packing materials and rigid packaging amounted to approximately 20 million pounds during 1990; 16 million pounds were estimated to have been recovered during 1989. This converts to 1.1 percent in 1990 as compared to approximately 0.9 percent in 1989. These recovery rates were established by conducting interviews with reclaimers closest to the end-product as possible. Means of collecting the material was not assessed.

Recovery of most resin types will increase in the future as more postconsumer plastic reclaimers accept mixed plastic bottles and as additional end uses for the processed material become available.

Current recovery consists largely of bottles due to their being easy to identify and handle/sort as opposed to films, flexible containers, and non-container products such as durables and non-durables with plastic components.

Emerging factors will lead to recovery of a more diverse stream of postconsumer plastic as time progresses. In particular, a solution to cross-contamination (such as a regional or nationwide campaign to promote recyclability) and market availability/stability (potentially through legislation or technical assistance to product manufacturers as to the benefits of and uses for PCR) will improve the recoverability of plastics in the future.

Potentially Recoverable Plastic

Potentially recoverable plastic consists of those plastic products which have certain physical characteristics or collection channels already in place which improve their chances for recovery in the near future. Custom PET bottles, from Spic and Span to Gatorade have a significant potential to be targeted for residential recycling. An effort is already underway to target these bottles with NAPCOR's "Look Out for Number One" campaign. Unfortunately raising awareness of recyclability through NAPCOR's public relations campaign is not enough to actually get bottles recycled. Markets have to be behind this effort and support recovery of these bottles. Reduction of cross-contamination is one key to getting market support, and this will be achieved only by developing of PET/PVC sorting technology, or elimination of PET look-alikes and PVC cap liners. PET could also be recovered from photographic film products, strapping, and food service items such as PET Solo cups. As long as there are stable markets and valuable end products, PET products can be targeted for recovery.

There may be potential to recover HDPE laundry and other household cleaning product containers. An increased recovery of these postconsumer pigmented bottles could be absorbed by end-market demand, although recycled content legislation may be needed to encourage end-product manufacturers to switch to PCR. This is particularly important since recent reclaimer comments suggest that relatively few high value end markets for processed pigmented HDPE bottle material are available. Higher rates of recovery of pigmented HDPE bottles will depend on more cost-effective sorting, development of value-added applications, and, for the short-term, content legislation.

Also in the HDPE family, film holds potential to be recovered. The factor influencing its recovery will be ease of identification or mixed film processing since film is commonly made from LDPE/LLDPE, PVC, and PP, as well as HDPE. Although Europe has been building equipment and technology for reclaiming highly contaminated film for over 20 years, the technologies are not directly applicable to bags because their design was for much thicker and agricultural film rather than thin grocery bags. Agricultural film in this country is recoverable and should be targeted for greater success.

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Based on conversations with industry sources, HDPE film bag recovery programs are being widely implemented by retailers and hold some promise for contributing to recoverability. Since generally the manufacturer of the original grocery bag is taking it back to put into a lower grade bag such as trash bags, end-market demand and processing capacity for these materials have been addressed. However, there remain some contamination concerns due to inks, food waste, and cross-contamination. Hence film grocery bag recycling may continue to be limited to end products that are dark and lower grade rather than a closed loop system putting reclaimed grocery bags back into grocery bags. Typically grocery bags are light in color and relatively thin. Therefore, forgiveness for poor PCR quality is low. Given the activity of Rhino X and the three film recycling start-up facilities mentioned earlier, better data on film recovery should be available soon.

Additional potential exists for HDPE drums, crates, pallets, pails and wire cable. Crates and pallets hold exceptional promise since content legislation could provide an outlet for reclaimed resins to go into these products.

Due to the relatively large volume of LDPE film that must be collected in order to ship it cost effectively and contamination issues mentioned previously, levels of residential postconsumer LDPE film recycling have been low in the past as reflected in Table 2-1. There is so much LDPE film available however that it should be targeted for recovery. LDPE appears in retail grocery bags, shrink and stretch wrap, and small quantities of trash bags. All of these items could best be recovered from commercial or industrial sources rather than from residential programs. Supermarket collection of LDPE is growing and represents a more convenient collection point than curbside. Due to the large quantity needed to cost effectively handle the material, non-residential sources are generally a much more practical source of supply. Though only small quantities of this film have been recovered in the past, there is capacity to reclaim the material which could be expanded if there were available supply. Like HDPE bags, retail programs will play a large role in the recovery of LDPE film bags. Moreover, content legislation will drive their recovery. A processing facility for flexible packaging is being built in New York by North American Plastics Recycling. The facility will be primarily targeted for materials used for commercial and industrial sources of flexible film plastics due to the relatively large supply and uncontaminated materials.

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Polypropylene rigid containers, commercial film such as bale wrap, and small quantities of PP consumer bottles are technically recoverable, but only if effective sorting technology is developed. This resin is successfully recycled in battery casings primarily due to ease of identification. In bottle and film applications, due to small available quantities, cross-contamination, and lack of processing capacity, recovery is greatly hindered.

The recovery of other residential plastic products such as durables and non-durables will be based on their ease of recognition by the general public and channels available for their collection and recovery. For instance, PP battery casings were recovered at a rate approaching 90 percent in Calendar Year 1990 since recognition of the product is easy, cross-contamination was not an issue, content contamination (battery fluid) was handled by the lead smelting operation, and a clearly defined channel for the material's collection and processing was established. Recovery of other residential postconsumer durables and non-durables will need to be developed based on the same handling and processing criteria if cost-effective recovery channels are to be developed.

Although residential PS recovery is severely limited by a number of factors, especially the high cost of transportation, there have been efforts to accomplish recovery primarily due to the high visibility of products containing this resin. PS plants are taking a loss which is expected in an R & D phase, but if the financial forecast continues to be gloomy, expansion plans are tenuous at best, and plants may be threatened with closure. The potential for recovery that does exist will depend greatly on collection programs sponsored primarily by food service chains, schools, offices, and other commercial and institutional facilities due to the relative inefficiency of collecting such material at curbside or through residential drop off programs. In all, many household consumer products made from PS, PP, and PVC have significant barriers to recovery.

Relatively speaking, those resins with existing recycling infrastructures such as PET and HDPE can be expanded to include a broader definition, such as custom PET instead of just PET soft drink bottles. Additionally, other bottles such as PP and PVC may be potentially recoverable in existing bottle recycling systems. Finally, various film grades will likely become more recoverable through commercial and retail recovery programs.

Plastic Not Likely To Be Recovered Immediately

As discussed above, Polystyrene will likely be one of the most difficult residential plastic to recover, especially in food service applications. Only minor quantities of postconsumer PS packaging have been recycled in the past due primarily to the high volume to weight ratio of PS packaging and food contamination. In addition, PS rigid containers contribute only minimally to a typical household's waste stream, reducing the potential for cost-effective recovery. What little activity there has been in PS recycling does not target residential but rather institutional or commercial waste because the majority of such postconsumer PS is generated in commercial and institutional settings.

Two major efforts to recycle polystyrene have been initiated to date. The National Polystyrene Recycling Company ("NPRC", formed by Amoco, ARCO, Chevron, Dow, Mobil, Novacor, Fina Oil, and Huntsman Chemical Corporation) set out to recycle polystyrene from schools, universities, restaurants and businesses. However, the newest plant in Bridgeport, New Jersey is having difficulty getting material due to shipping costs, as well as low participation. More recently, foam packaging manufacturers have united to reprocess used packaging foam back into like products for a closed loop system. A total of 81 companies have joined to announce 115 potential plant locations that will serve as collection points for used expanded polystyrene protective foam packaging ("EPS"). The group effort has been titled the Association of Foam Packaging Recyclers ("AFPR"). Major retailers, companies like Mail Boxes, Etc., and manufacturers such as Hewlett Packard and Honda will be both generators and customers. This approach is consistent with the recommendation to target commercial collection of PS rather than residential.

Postconsumer PVC recycling has been relatively insignificant in the past due to the fact that only small quantities are used in packaging applications when compared to other polymers. Also, it appears that the current high costs of manually sorting PVC, and the threat it poses to PET may restrict recovery of PVC bottles. Yet, appropriate sorter training could significantly reduce the costs of sorting PVC bottles, especially if the other clear bottle streams have been removed (clear PET soft drink and custom bottles). As mentioned previously, several operations in the Northeast plan to continue separating PVC bottles. Pipe and conduit, siding, and wire cable are potentially recoverable, but again face

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significant barriers and would be better addressed through the commercial/industrial stream of waste.

Polypropylene bottle recovery is likely to remain soft until the barrier of automatic sorting technology is overcome. Additionally, the fact that PP is a very cheap material to produce will limit its recovery. Although some Northeast operations are separating PP bottles for certain end-market applications, a question remains as to whether these and other potential markets would continue to absorb the supply or an expanded supply of sorted PP bottles without content legislation.

All three of the above discussed resins exist in such small quantities of readily identifiable products or have low values as both a virgin and reclaimed resin, that recovery will be severely limited. Each, if recoverable in any measurable quantity, would be better addressed in recovery programs targeting the commercial and industrial sector such as the AFPR effort.

Also not likely to be recovered in residential streams are HDPE injection grade products. Only a small quantity of this material is generated by residential streams, such as margarine tubs and baby wipe containers, and the high handling/processing costs along with the threat to bottle grade material make it a less desirable target for recovery.

The recoverability of all of the above products/resins' is somewhat related to cost effectiveness of collection and sorting, although even once sorted there may not be sufficient quantities to justify processing plants except as a part of a mixed plastic waste stream. Methods for automatically sorting postconsumer resins are well into the development stages and include automatic whole bottle sorting by resin type, micro-sorting which would enable a plastics reclaimer to separate various resins after the material has been flaked, and color sorting within resin families using fiber optics. Processing material to flake instead of bales at the collection point would also reduce transportation costs. However, some processors fearing contamination will not accept granulated plastics. Sorting technologies and costs will be discussed in detail in the following section.

CONCLUSIONS

In terms of recovery, postconsumer resins/products can be divided into three groups.

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- (1) Resins/products which are being successfully recovered at the present time, include PET soft drink bottles, HDPE milk and water jugs, HDPE pigmented consumer bottles which have not contained chemicals, PP battery casings, and HDPE soft-drink base cups.
- (2) Resins/products which have good potential to be recovered in the future, but must overcome relatively minor barriers to recovery, including custom PET bottles (for Spic and Span and Gatorade), PET x-ray film, HDPE household chemical bottles, HDPE and LDPE/LLDPE film bags.
- (3) Those resins/products which currently face significant barriers to recovery, including PS packaging from residential generators, PVC bottles, and PP bottles. These barriers may be overcome by public/handler and education and commercialization of automated sorting technology.

There are a number of resins/products which might be targeted for recovery from institutional/commercial/industrial generators, including PET x-ray film HDPE stretch and shrink wrap, agricultural film, HDPE crates, drums, pallets, and pails, PVC pipe and conduit, PVC siding, and PS food service products.

RECOMMENDATIONS

The following recommendations should lead to increased recovery of a broader range of plastics over a longer time period. Additionally, if pursued, these recommendations should improve existing recovery programs.

- Mixed residential film recycling has potential for recovery but should not be pushed forward too rapidly. Rather, observation of the progress in facilities such as Rhino-X, Petoskey Plastics, Inc., Southeastern Recycling, and North American Plastics should precede the implementation of large-scale programs. Alternatively, film should be targeted for commercial and industrial recovery.
- An education program for reclaimers of silver from X-ray film is recommended, to raise awareness about the

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recyclability of PET film. Perhaps a match program of PET reclaimers with silver reclaimers could also be undertaken, to make sure the PET material has an outlet prior to the silver reclaimer making changes in solutions.

- Because of stable markets, valuable end products, and a well-developed infrastructure, PET bottles should be targeted for recovery, although focus should be placed on designing PET non-soft drink bottles for recyclability and public education stressing bottle rinsing and drainage.
- Processors of PET and HDPE could cooperate with the PVC industry to sort and make available for shipment PVC bottles from mixed streams.
- Product definition (i.e., the designation of containers by product type, brand name, or shape, such as soft drink or narrow neck bottles) should be used to enhance public education. Number codes should only be used if markets are secured for the wide range of materials generated by using the number codes such as custom PET bottles or injection grade HDPE.
- Proper drainage of bottles should also be emphasized in public education, particularly with regard to bottles containing hazardous waste.
- A modest training program to help full-time sorters in plastic sorting facilities identify containers such as PET look-alikes (e.g., PVC Wesson Oil bottles) could improve recovery of the plastic bottle stream.
- EPA should take the lead in re-examining the recommendation for proper disposal of home use medical waste in light of contamination of recyclables, especially those generated in mixed waste processing facilities.
- To balance virgin resin production and price cycles, industry could consider the development of recycling capacity on the front end of petrochemical plant expansions.
- Reduction of cross-contamination through recyclability campaigns, technical assistance, or legislation should be pursued.

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- The public procurement of recycled plastic products would greatly improve the absorption of postconsumer products. Mandated public procurement of recycled plastic products at the local, state, and federal levels of government should be strongly supported.

Section 3

THE ECONOMICS OF SORTING POSTCONSUMER PLASTICS

INTRODUCTION

Section 3 consists of two distinct topics. The first part consists of a discussion of the methods for postconsumer plastics collection, the perceived advantages and disadvantages of each, and the costs of each type. Recommendations for increasing volumes collected and minimizing contamination are also addressed.

The second part of Section 3 addresses centralized sorting of postconsumer plastics, selecting plastics for sorting, and the types of sorting, including manual and automated sorting techniques and macrosorting and macrosorting technologies. A discussion of methods for improving plastic handling economics is also included.

Postconsumer PLASTIC PROCESSING COSTS

The recycling of residential postconsumer plastics presents challenges not found with other traditionally reclaimed materials, such as newspapers, glass containers, and aluminum cans. Unlike these products, household plastic containers are constructed of a wide range of individual polymer types, each with differing chemical and physical properties. Many consumers cannot easily tell one plastic from another. For example, many people do not realize the difference between a PET bottle and a PVC bottle, and the need to keep them separate. Literature, including illustrations of both acceptable and nonacceptable products, must be distributed as part of an aggressive public education program, in order to inform the participants of plastic items included in the program.

Sorting plastics is necessary since reclaimed plastic of mixed resin types exhibits markedly inferior physical and marketing qualities compared to individually reprocessed resins. The limited demand for products manufactured from such commingled plastics is insufficient to solely support most plastics recycling programs and infrastructures.

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Sorting costs are one of the most important components of a postconsumer plastics recovery program. Various materials recovery facility ("MRF") studies¹ and other studies² have determined a range of sorting costs from 0.5 cents per pound to 5.0 cents per pound (\$10 per ton to \$100 per ton). Average costs for sorting are generally in the 2.0 cents per pound (\$40 per ton) range. Average costs for baling or granulating are in the 1.5 cents per pound (\$30 per ton) range, transportation costs average 2.0 cents per pound (\$40 per ton), cleaning costs are about 10.0 cents per pound (\$200 per ton), and pelletizing costs average 6.0 cents per pound (\$120 per ton). Collection costs vary a great deal from program to program, but one study to be discussed later in this section suggests an average cost of plastics collection of 4.6 cents per pound of plastic. Costs of handling contaminated materials and disposal of reject and residue are included in each of the preceding costs.

Table 3-1
Average Post-Consumer Plastics Reprocessing Costs
(cents per pound)

Process	¢/lb.
Collection	4.6
Sorting	2.0 - 4.0 ⁽¹⁾
Baling/Granulating	1.5/5.0
Transportation	2.0
Cleaning	10.0
Pelletizing	6.0
Total Costs	26.1 - 31.6

⁽¹⁾ High range reflects increased sorting costs necessary for granulating as compared to baling.

⁽²⁾ R. W. Beck and Associates, June 1991.

¹ "Current and Target Recovery Rates for Plastics Packaging in Oregon", by Resource Integration Systems, Ltd. ("RIS"), October 1990.

² "Post-Consumer Plastics Recycling Report for Mobil Chemical Company", by R. W. Beck and Associates, June 1991.

Commercial postconsumer and industrial scrap plastics, on the other hand, can provide cleaner, more homogeneous, recyclable plastics. Often, large amounts of such plastics are collected at the place of business. North American Plastic Recycling Corporation of Fort Edward, New York is building a centralized processing facility capable of reclaiming flexible plastic packaging (mostly film) from commercial and industrial generators.

Sorting can take place at various stages of the postconsumer plastic reclamation cycle. It can take place at the household, where the homeowner or resident sorts the plastic resins/products into separate bins. Sorting can also be done by the collection vehicle operator at the curb. Sorting can also be done at a handling facility in which a conveyor belt feeds plastic feedstock to sorters on a picking line, wherein each worker removes items of a specific type. Finally, sorting can be done at the reprocessing stage of reclamation. In this phase, differences in physical characteristics among resin types are used to separate the various processed plastics.

Since sorting is such an important part of the postconsumer plastic recycling budget, it is necessary to sort as efficiently as possible, to make plastics recycling programs economically feasible. This section of the report seeks to analyze barriers to the economical sorting of plastics and strategies for overcoming these barriers. Additionally, a discussion of the most cost-effective solutions to postconsumer plastics sorting/collection is also provided.

Postconsumer PLASTICS COLLECTION METHODS

Background

Three primary methods for the collection of residential postconsumer plastics are in general use: (i) curbside collection, (ii) public drop-off facilities, and (iii) buyback centers. Table 3-2 provides a listing of the number of reported curbside, public drop-off, and buyback center programs for the collection of residential postconsumer plastics for each of the ten Northeastern states. This data was obtained from the recent National Postconsumer Plastics Collection Survey Report (the "Collection

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Survey") prepared for The Council For Solid Waste Solutions by R. W. Beck and Associates.

Table 3-2
National Post-Consumer Plastics Collection Survey
Collection Method Responses for Northeastern States

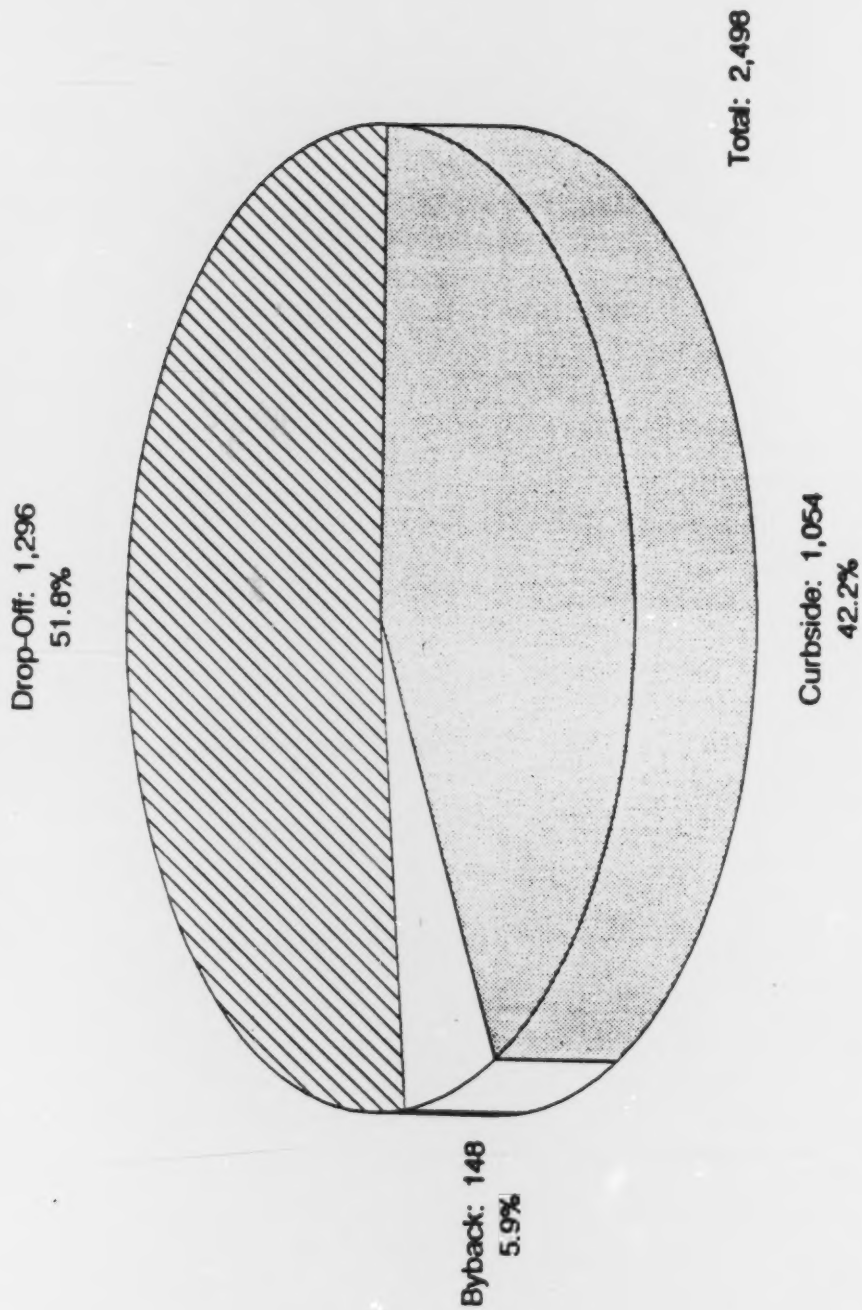
State	Number of Communities with:							
	Access to Plastics Recycling	Percent of Response	Curbside Collection	Percent of Curbside Collection	Drop-Off Collection	Percent of Drop-Off Collection	Buyback Collection	Percent of Buyback
CT	67	4%	42	4%	62	5%	3	2%
DE	3	0%	0	0%	3	0%	0	0%
MA	101	6%	27	3%	84	7%	11	7%
ME	87	5%	10	1%	84	7%	6	4%
NH	65	4%	32	3%	61	5%	1	1%
NJ	282	16%	207	20%	199	15%	1	1%
NY	606	35%	447	42%	395	30%	105	71%
PA	391	23%	265	25%	312	24%	20	13%
RI	15	1%	13	1%	5	0%	0	0%
VT	93	6%	11	1%	91	7%	1	1%
Total	1,710	100%	1,054	100%	1,296	100%	148	100%

Source: Council for Solid Waste Solutions

The values shown are based on the results received from 21,000 surveys mailed to municipalities throughout the country with response rate of approximately 20%. The values shown indicate the relative numbers of collection programs among the different states, as well as relative numbers of the different types of programs present in each state or region. The values presented should not be taken to be the absolute numbers of programs present in the state or region, but as information about the relative mix of programs.

As can be seen in this table and on Figure 3-1, a total of 2,498 plastics collection programs [1,054 curbside (42.2%), 1,296 drop-off (51.9%) and 148 buyback (5.9%)] are reported in the ten Northeastern states. New York reports having 947 of these programs (447 curbside, 395 drop-off, and 105 buyback) whereas Delaware reports only 3 drop-off programs. The remaining states report number of programs somewhere between these two values.

Figure 3-1
Number of Types of Residential Plastics
Collection Programs in the Northeastern States



It is important to note that these 2,498 programs are operating in 1,710 individual communities; which signifies that many communities operate more than one type of program. 606 of these communities are located in New York and 3 are in Delaware. Curbside programs are thus available in 61.6% (1,054 programs in 1,710 communities) of the communities recycling plastic, drop-off programs are available in 75.79%, (1,296 programs in 1,710 communities) and buyback programs are present in 8.65% (148 programs in 1,710 communities) of communities recycling plastic.

It is interesting to note that the 1,710 northeastern communities responding affirmatively to having access to at least one type of residential postconsumer plastic collection program represent 46% of the national total of 3,709 communities based on preliminary survey results.

In most instances, plastics are collected in these communities in conjunction with other recyclables such as glass, newspaper, and cans. It is generally accepted that, whichever collection method is used, the most efficient plastics recycling programs initially included plastics in their original design. This allows for the proper sizing of collection vehicles and storage containers to efficiently handle the volumes of the various recyclables collected.

Curbside Collection

Introduction

Curbside collection is the most convenient program for a municipality's residents and the most efficient in terms of quality (generally only 5 to 10% contaminants experienced) and quantity of recyclables collected. As a result, this method is becoming increasingly popular. Curbside collection, however, tends to be more costly than other methods. Curbside collection programs may be either publicly or privately operated.

Most curbside collection programs are supported by voluntary participation of the eligible households on the route. In general, citizens are asked to place their plastics in bins (or other recycling containers) for collection once a week, although bi-weekly and monthly pickup frequencies also occur. It has been frequently noted that households that participate in

curbside recycling programs set out approximately 70 percent or greater of all plastics designated for collection in such programs.³

Compaction at the Collection Point

One of the primary problems associated with curbside collection of plastics has been the need for increased truck capacity to handle the amount of plastic collected. In the not too distant past, municipal curbside collection commonly focused exclusively on non-plastic recyclables (i.e., aluminum and steel cans, glass bottles, and newspapers; items with relatively high weight to volume ratios). Plastic containers, however, take up a lot of room but provide little total weight. In many cases, haulers providing the curbside recycling service require an increase in the collection fee when plastics are added to a curbside program, primarily due to the increased truck capacity required to service the same number of households. For this reason, on-board compaction of plastics will be important in reducing the cost of collecting postconsumer plastics at the curb.

Recently, several very efficient on-board plastic bottle compactors have come on the market. In fact, well over 300 such units, capable of compaction rates of up to 20:1, are now being used throughout the country.⁴ Recommended technical specifications for an on-board plastics compactor are shown below in Table 3-3. A unit as described would cost approximately \$7,500. Assuming an amortization life of seven years, such a compactor would cost about \$5 per day of operation.

The compaction of collected plastics may also be accomplished by the individual resident. The degree of compaction and the impact on collection vehicle capacity will depend on the mix of plastic resin/products collected. Curbside participants may be asked to place a variety of plastics in curbside collection bins. Normally, PET soft drink bottles and HDPE milk jugs at a minimum are collected. These items, as well as pigmented HDPE bottles, are often the only plastics collected in

³ "Plastics Recycling: An Overview" by The Plastics Recycling Foundation and The Center for Plastics Recycling Research.

⁴ "Densification Options for the Collection of Recyclable Plastics", by Frontier Recycling Systems, Inc. and Moore Recycling Associates, May 1990.

**Table 3-3
On-Board Plastics Compactor -
Recommended Technical Specifications**

Storage capacity:	300-400 pounds, 0.75-1.00 cubic yard volume
Weight:	<2,500 pounds
Maximum dimensions:	H = 60", W = 26", L = 96"
Loading Height:	45-60"
Cycle time:	20 seconds
Maximum load cycle:	0.10 cubic yards
Power source:	4-6 gallons per minute, 1,500-2,500 pounds per square inch
Minimum platen pressure:	50 pounds per square inch
Discharge operations:	5 minutes maximum, height allowing unloading into roll-off bin, controls in cab
Loading Configuration:	Dual side loading
Platen regulator:	Springback control
Contaminant disposal:	Leakage containment

Source: *The Council For Solid Waste Solutions, 1991.*

a curbside program. They are easily identifiable to both homeowner and vehicle operator/sorter, account for the majority of residential postconsumer plastics bottles, and are in the most demand in today's market. Table 3-4 provides estimates regarding average recovery levels on a per household basis of plastic products commonly collected in curbside programs. Additionally, average densities for resident-compacted materials ("Step on it Program") are also listed. Flattening by the resident will not achieve volumes as low as an on-board compactor because of the greater pressure exerted by a automated compactor. In either case, compacted containers may create difficulties for many types of automated sorting equipment, trommels and eddy currents, which depend on containers having their original shape. The collection program, i.e., use of on-board compaction or flattening by residents, should be coordinated with the processing program to avoid these difficulties.

Table 3-4
Estimated Recovery Levels of
Plastic Resins in a Curbside Program

Category	Resins Collected	Estimated Recovery Level pounds/household/year	Estimated Density pounds/cubic yard homeowner compacted
Soda Bottles	PET	5-11	30-45
Milk Jugs	natural HDPE	5-10	25-30
Soda Bottles and Milk Jugs	PET, natural HDPE	8-17	30-40
Beverage Bottles	PET, natural HDPE, clear PVC	8-18	30-40
Detergent and Bleach Bottles	colored HDPE	1- 2	35-50
All Clean Bottles	PET, natural HDPE, colored HDPE, colored PVC, PP, multilayer	15-24	40-50
All Rigid Containers	PET, HDPE, PS, PVC, PP, multilayer	20-30	45-55
All Clean Plastics	PET, HDPE, LDPE, PS, PVC, PP, multilayer	25-40	N/A

Source: The Council For Solid Waste Solutions, "How to Implement a Plastics Recycling Program"

Commingled Versus Separated Curbside Collection

Deciding between commingled recyclables collection (which requires that the recyclables be sorted after collection) and separated collection (which requires either the resident or collector to separate the material at the curb) involves the weighing of ease of collection against ease of processing. Additionally, such a choice involves comparing the costs of utilizing a materials recovery facility ("MRF") for sorting, if available, to the costs associated with curbside sorting of plastic by the vehicle operator/helper.

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Some of the advantages of commingled collection include:

- Increased resident participation, since homeowners can place all recyclables in just one bin.
- Garbage collection vehicle may also be useable for recyclable collection.
- Lower collection labor costs.

Disadvantages of commingled collection include:

- Need for a sorting facility.
- Contamination of other recyclables by broken glass.
- Extreme high cost of broken glass.

Advantages of separated collection include:

- Less cross-contamination of recyclables.
- Eliminates need for construction or use of a separate sorting facility, a materials recovery facility ("MRF").

Disadvantages of separated collection include:

- Requires a compartmentalized truck, which may reduce collection efficiency and thereby increase costs.
- Increased labor costs for collection if vehicle operator separated, theoretically lower participation if resident separated.

Curbside Collection Economics

It is extremely difficult to determine accurate plastics collection program costs. Many municipal plastics collection programs do not provide cost information, either because they do not have data on the cost of plastics collection [perhaps data is available only regarding total recycling program (plastics, aluminum cans, glass, etc.) costs], or because such costs are confidential. Also, it is difficult to find two plastics collection programs that are run identically, therefore, all comparisons may be biased. For instance, one may justifiably expect overall collection costs to be greater (on a dollars per ton basis) for a program accepting all household plastics

than for a program accepting only PET soft drink bottles and HDPE milk jugs.

Nevertheless, a recent study⁵ performed for The Council For Solid Waste Solutions ("CSWS") attempted to quantify costs for eighteen postconsumer plastics curbside collection programs. In order to make the respective values as comparable as possible, certain common assumptions regarding cost factors such as wages, insurance, fuel, and maintenance costs were incorporated, and modified program costs were derived. These calculated plastics collection costs ranged from \$35 per ton to \$199 per ton (1.8¢ per pound to 10.0¢ per pound), with an average value of \$92 per ton as seen in Table 3-5. This reflects an average cost of approximately 4.6¢ per pound of plastic collected, an amount which, in general, is comparable to similar costs reported in other studies. Three northeastern community collection programs were included in the sample. As can be seen in this table, average plastics collection costs for this geographical area were \$138 per ton, or 6.9¢ per pound.

The significant variations in costs are attributable to differences in the number of materials collected, the number of separations performed at the curb, frequency of collection, crew size, type of truck used, and other variables.

CSWS also conducted a case study of a municipal recycling program that included curbside collection/sorting of aluminum cans, steel cans, clear, green, and brown glass, PET containers, HDPE containers, newspaper and corrugated paper. The goal was to obtain an unbiased estimate of collection costs for plastics on a weight basis. This methodology is also appropriate for determining similar costs for the other recyclables. This methodology also avoids inflated and unfair cost estimates often reported for adding plastics to a collection program that arise from allocating all incremental costs recognized by a community adding plastics to an existing program (such as the entire cost of a new collection vehicle if existing capacity is insufficient). The purpose of the case study was to:

- i) allocate the cost of labor for sorting/loading each recyclable based on the percentage of total time spent sorting/loading each material;

⁵ "Collection Method Profiles and Material Recovery Facilities Assessment", by RIS, July, 1990

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Table 3-5
Calculated Plastics Collection Costs in
18 Sample Communities

Community	Collection Costs (\$/ton)	Collection Costs (¢/lb)
Philadelphia, Pennsylvania	\$196	9.8¢
Somerset County, New Jersey	\$118	5.9¢
West Warwick, Rhode Island	\$101	5.1¢
Northeast Average	\$138	6.9¢
Arlington Heights, Illinois	\$ 47	2.4¢
Champaign, Illinois	\$ 98	4.9¢
Charlotte, North Carolina	\$ 73	3.7¢
Cincinnati, Ohio	\$122	6.1¢
Edmonton, Alberta (North)	\$ 94	4.7¢
Edmonton, Alberta (South)	\$ 74	3.7¢
Gainesville, Florida	\$107	5.4¢
Palm Beach, Florida	\$ 83	4.2¢
Palo Alto, California	\$ 40	2.0¢
Phoenix, Arizona	\$199	10.0¢
Portland, Oregon	\$ 35	1.8¢
San Francisco, California	\$ 74	3.7¢
Seattle, Washington (North)	\$ 43	2.2¢
Seattle, Washington (South)	\$ 43	2.2¢
Toronto, Ontario	\$121	6.1¢
Overall Average	\$ 92	4.6¢

Source: "Collection Method Profiles and Material Recovery Facilities Assessment" by RIS,

- ii) allocate the equipment-related costs of each recyclable based on the percentage of total vehicle capacity devoted to that material; and
- iii) divide non-loading/sorting labor costs and overhead equally to each recyclable collected.

The particular program studied was chosen as fairly typical. It consisted of a 3,000 home community (8,000 population) with a weekly collection frequency and 65-70% weekly participation. Approximately three tons of materials per day were collected in a truck of 29.6 cubic yard capacity. The private contractor responsible for collection charges \$270 per day to serve 600 homes.

One-hundred dollars of this amount is attributable to labor costs. The driver/sorter spent one-half of his time sorting/loading materials, of which 17% was spent on plastics, yielding a daily cost of \$8.50.

Another one-hundred dollars is attributable to equipment-related costs. The typical plastics compactor/storage unit previously described occupies 3.6 cubic yards, or 12% of the truck's payload capacity. Thus, the daily cost allocated to plastics is \$12. The \$5 attributable to the plastics compactor must also be included to reach a total daily cost of \$17.

Non-sorting/labor costs total \$50. The remaining \$70 are fixed costs. Thus, \$120 is divided among the eight material types collected, resulting in a cost to plastics of \$15.

Total costs allocated to plastics are, therefore, \$40.50 per day. Typically 300 pounds of plastic are collected daily, thus total costs on a per ton basis are \$270.

Revenues from the sale of plastics fluctuate, as do the prices paid for other commodities, but are assumed to be in the \$120 to \$160 per ton range. Thus, net collection costs are calculated to be in the \$110 to \$150 per ton range. This estimate of 5.5 to 7.5 cents per pound is comparable to, although slightly higher than, the 4.6 cents per pound average of the eighteen programs surveyed and discussed earlier. In fact, three of the programs surveyed reported actual collection costs within this fairly narrow range.

It is important to note here that neither of these estimates of net collection costs includes costs associated with baling of the plastics or transportation of such bales to market. A recent study prepared for a confidential client by R. W. Beck and Associates estimated typical baling costs to be approximately 1.5 cents per pound (\$30 per ton). Transportation costs for baled material were based on another recent Beck study for The Council

For Solid Waste Solutions. This report estimated the cost of transporting a truckload of baled plastic to a market an average (approximately 200 miles) distance away to be 2.0 cents per pound (\$40 per ton). Including these two items in estimates of collection costs increases such costs to \$180 to \$220 per ton (9.0 to 11.0 cents per pound) for the case study municipality, and to \$162 per ton for the eighteen city average (8.1 cents per pound).

Drop-off Facilities

Introduction

Drop-off programs are commonly used in areas which would not be economically able to support a curbside recycling collection program. As previously mentioned, 1,053 of the 2,106 reported residential postconsumer plastic programs in the Northeast are classified as drop-off programs. The main advantage of drop-off programs is the lower recycling program costs, typically one-third to one-half of the cost of curbside programs on a per ton collected basis. A recent study of plastic drop-off programs prepared for The Oregon Department of Environmental Quality⁶ concluded a national average cost per ton of collected material to be \$34 (1.7 cents per pound), with a range of \$25 to \$44 per ton (1.3 to 2.2 cents per pound). However, participation rates tend to be much lower than curbside programs. Only 10 percent of the collectible plastic available in a typical residential household's waste stream is normally captured with this program type, as opposed to 70% with a curbside program. On the other hand, some programs with public education comparable to curbside programs can achieve recovery and contamination rates which are comparable to curbside programs.

Although the costs to a municipality for a drop-off collection program may well be substantially less than the costs for a curbside program, another factor should be kept in mind. A recent survey of participants at a retail drop-off site, as part of a study being performed for Procter & Gamble by R. W. Beck and Associates, revealed that the vast majority were making a trip to the location solely to deposit plastics. In other words, participants were not combining their trip to the facility with their other outings. Therefore, the energy expended (and the pollution created)

⁶ "Current and Target Recovery Rates for Plastics Packaging in Oregon", by Resource Integration Systems, Ltd., Portland, Oregon, October 1990.

by all of the participants' vehicles as a result of driving to the drop-off site is far greater than the energy spent by a curbside collection vehicle. Public education programs designed to convince citizens to combine their trips to drop-off recyclables with shopping or other excursions should be considered. It also makes sense to locate drop-off centers at places which encourage combined trips, such as a transfer station and shopping center parking lots.

Drop-off programs are also important due to the fact that they represent the majority of the programs responsible for accepting the less commonly collected resin types, such as LDPE and polystyrene. Table 3-6, which again is based on preliminary responses obtained for the Collection Survey, illustrates this point. For instance, of the 168 communities in the Northeast reporting that they provide LDPE collection, 119, or 70.8%, have access to drop-off facilities for this resin type, whereas only 53, or 31.5%, and 3, or 1.8% have access to LDPE collection in their community by curbside and buyback programs, respectively. Once again, the responses shown are to illustrate relative numbers of programs, and should not be construed to represent actual numbers of programs in operation in the Northeast. The importance of this fact is that although curbside and buyback programs are responsible for the collection of a significant portion of commonly collected resin and product types (i.e. PET soft drink bottles, HDPE milk/water/juice jugs), the vast majority of the less common resin and product types are collected through drop-off programs.

Much greater contamination levels than those experienced with curbside programs are often realized in drop-off programs, sometimes approaching 30% to 40%. Since the plastics are at times collected in a container resembling a garbage dumpster, residents will occasionally throw general refuse in the container. This is especially important currently since plastic handlers and reclaimers have become increasingly unwilling to accept plastics with excess quantities of contaminants due to increased pressure on profit margins resulting from lower virgin plastic prices (see Section 2). The handlers not only realize increased labor costs for sorting, they are faced with the problems and significant expense of disposing of non-desired plastics and other materials.

An ongoing project being performed for Procter & Gamble by R. W. Beck and Associates seeks to determine causes of these contamination problems plaguing many drop-off programs and to offer suggestions to improving the quality of materials collected.

Table 3-6
National Post-Consumer Plastics Collection Survey
Plastic Resin Response Rate by Collection Method

RESIN CATEGORY	CT	DE	MA	ME	NH	NJ	NY	PA	RI	VT	REGION
# of Communities with Plastics Collection	59	3	75	34	47	231	540	345	13	64	1,411
PET Soft-Drink Bottles											
Curbside	33	1	14	1	27	168	353	220	11	3	831
Drop-Off	37	2	45	10	46	156	260	268	3	31	858
Buyback	3	0	9	5	0	0	104	18	0	0	139
Total ⁽¹⁾	42	3	59	14	47	229	470	335	13	32	1,244
PET - Other Bottles											
Curbside	32	1	12	2	7	107	373	211	2	3	750
Drop-Off	38	2	44	10	26	127	288	259	1	50	845
Buyback	0	0	2	1	0	0	0	16	0	0	19
Total ⁽¹⁾	41	3	52	13	27	157	471	319	3	51	1,137
HDPE - Natural Color											
Curbside	37	1	19	4	27	165	392	221	11	24	901
Drop-Off	56	2	62	32	46	156	345	270	3	62	1,034
Buyback	0	0	2	0	0	0	0	16	0	0	18
Total ⁽¹⁾	59	3	73	33	47	228	535	337	13	64	1,392
HDPE - Pigmented											
Curbside	35	1	15	4	27	150	387	197	0	24	840
Drop-Off	41	2	54	19	45	141	322	215	0	61	900
Buyback	0	0	1	0	1	0	0	3	0	0	5
Total ⁽¹⁾	44	3	63	20	47	207	509	274	0	63	1,230
PVC											
Curbside	1	0	2	0	0	31	278	16	0	0	328
Drop-Off	4	2	14	4	7	38	222	22	0	0	313
Buyback	0	0	1	0	1	0	0	2	0	0	4
Total ⁽¹⁾	4	2	15	4	8	52	350	40	0	0	475
LDPE											
Curbside	1	0	0	1	0	29	17	5	0	0	53
Drop-Off	4	2	9	17	3	6	61	16	1	0	119
Buyback	0	0	0	1	1	1	0	0	0	0	3
Total ⁽¹⁾	4	2	9	18	4	34	76	20	1	0	168
PP											
Curbside	1	0	2	0	0	19	0	8	0	0	30
Drop-Off	4	2	19	5	2	17	0	19	0	0	68
Buyback	0	0	1	0	1	0	0	1	0	0	3
Total ⁽¹⁾	4	2	20	5	3	27	0	28	0	0	89
PS											
Curbside	0	0	0	0	0	2	9	2	0	1	14
Drop-Off	3	1	13	5	9	4	34	5	0	8	82
Buyback	0	0	0	0	1	0	0	1	0	0	2
Total ⁽¹⁾	3	1	13	5	10	6	40	8	0	8	94
Other Resins											
Curbside	0	0	0	0	0	5	11	3	0	0	19
Drop-Off	2	1	9	3	2	6	13	4	0	0	40
Buyback	0	0	0	0	1	0	0	1	0	0	2
Total ⁽¹⁾	2	1	9	3	3	8	21	8	0	0	55
Miscellaneous											
Curbside	1	0	0	0	0	1	6	0	0	0	8
Drop-Off	5	1	4	3	1	3	11	3	0	0	31
Buyback	0	0	0	0	1	0	0	0	0	0	1
Total ⁽¹⁾	5	1	4	3	2	3	16	3	0	0	37

⁽¹⁾ Reflects number of communities within the state or region with access to at least one type of collection method for the specific resin/product type.

It has been concluded that two major factors are responsible for the high levels of contamination in drop-off programs. These two factors are related and provide evidence of the public's inability to distinguish between plastics. First, many people think that all plastics are the same, just as all glass bottles, aluminum cans, and newspaper are the same. In other words, they believe that a PET soft-drink bottle is constructed of an identical material to a PVC vegetable oil bottle. They do not realize that including this PVC bottle in a PET only collection container can cause an entire load of PET to be rendered useless when reprocessed. The placing of this PVC bottle in a drop-off container is often a result of the second factor, that is, inadequate container signage and related educational literature as to which specific plastics are included in the program and the condition of the plastics required for their acceptance (i.e. caps off, bottles rinsed, labels o.k., etc.).

Written instructions stating that only PET and HDPE are acceptable are meaningless to most people. Even stating that only plastics coded "1" or "2" are accepted is inadequate. Such items as margarine tubs, cups, bleach bottles, etc. coded "2" may or may not be acceptable as part of the drop-off program. Additionally, many plastic items are as yet uncoded, which often leads to frustration of the participant.

Pilot programs, such as the Procter & Gamble/City of Tampa, Florida program being tested in certain Tampa area supermarkets, have shown that the most effective signage is simple and easy to read and comprehend by the public. Therefore, signs utilizing minimal verbiage should be developed; they should contain pictures or illustrations of those plastics products that are accepted such as soft drink bottles, milk jugs, etc. Pictures have been shown to be much more effective in targeting desired plastics since they are easily recognizable to the public.

Lastly, it may well be worthwhile to have an attendant staff the drop-off site for a few weeks at the beginning of the program in order to help educate the public as to acceptable plastics and desired conditions of the items. It may also be of value to repeat this procedure on a regular basis as new individuals begin to participate in the drop-off programs or if the quality of material begins to diminish.

It is generally a good practice to begin a drop-off program with just a few common products being accepted, such as PET soft drink bottles and HDPE milk jugs. If additional markets become available for other

products, these products can always be added to the collected plastics at that time. If the public is informed that a previously accepted product is no longer included in the program, participant frustration may lead to their abandoning all recycling efforts. Additionally, it has been determined to be extremely difficult to get residents to delete a plastic product from any type of collection program, especially a drop-off type program. If this is necessary, appropriate signage revision and site staffing are vital to the program's continued success.

Since the drop-off plastics are usually collected by emptying the entire contents of the container into the collection vehicle, the collector does not have the opportunity to leave the unrecyclable plastics and other non-recyclable materials with the residents as would be the case with a curbside program. Typically, a brochure reminding the resident of the correct types of plastics to set out in the future would be left with the contaminants at the curb. Therefore, an important feedback mechanism used frequently in curbside programs is not typically available when operating a drop-off program, thus the elevated contamination levels generally found in drop-off programs.

Therefore, clear, concise, appropriately illustrated signage regarding accepted materials must be included at the drop-off site. Additionally, the site should be staffed at the program's onset and at regular intervals thereafter by informed staff members of the collection program, so that participants will be aware of which plastic products are included in the program and the desired conditions for their acceptance.

The following discussion deals individually with drop-off programs for plastic collection in rural areas, apartment complex plastic drop-off programs, and retail store drop-off programs, mostly for film.

Rural Drop-Off

For many rural communities, curbside collection of plastics, or other recyclables, is not economically feasible. In such cases, drop-off collection of plastics may be used. Drop-off containers should be located at areas that are easily reached by the majority of residents, and that are easily accessible by truck or rail for subsequent transport. Often, drop-off containers are placed at local landfills, especially in areas where municipal curbside garbage collection is not mandatory. Ideally, such facilities should follow the recommendations previously discussed in this section (regarding staffing of site, distribution of educational literature, beginning

with collection of just PET soft drink bottles and HDPE milk/water/juice jugs, etc.), in order to establish a successful pilot program. Modifications to add other plastics for collection can be done at a later time. It is vital that the drop-off site be equipped with a baler at minimum in order to prepare the collected material for cost-effective transport, as well as covered storage area for loose plastic collected and for process bales.

Apartment Drop-Off

Drop-off recycling is also frequently used in apartment and condominium complexes due to the centralized nature of refuse disposal typically used in such living areas. Again, participation rates are usually significantly lower than single-family curbside programs due in part to the transient nature of multi-family unit dwellers. As a result, it is not uncommon for multi-family drop-off programs to typically garner participation rates in the range of just 30 to 40 percent. This is fairly significant when one considers that approximately one-third of the U.S. population resides in multi-family housing.

Complex associations or apartment complex managers must continuously educate new residents as to the types of plastics that are recyclable and methods for recycling the materials in the complex. Again, applicable signage is also a key to the education of residents.

Retail Drop-Off

One rapidly growing type of drop-off program is retail store collection of certain postconsumer plastics.

These retail programs occur most often as supermarket-run facilities for the collection of plastic film bags, such as grocery bags, produce bags, etc. Supermarkets in the Northeast with plastic bag collection programs include Victory Markets, P&C Food Markets, Pathmark Stores, A&P/Food Emporium, King Kullen Groceries, Price Chopper, Wegman's Food Markets, Shoprite Stores, Purity, Star Market, and Roche Brothers. Additionally, certain retailers such as Wal-Mart and Kash n' Karry have begun plastic bottle drop-off collection programs. These retail programs have been plagued by the same type of problems occurring with municipal drop-off programs and discussed earlier. Also, all convenience stores, grocery stores, and liquor stores in northeastern states with

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beverage container deposit laws (Vermont, Maine, Connecticut, Delaware, Massachusetts, and New York) are required to accept plastic bottles for refunds.

It has been estimated that typical grocery bag recycling programs attract customer participation rates of approximately 35 percent, based on work done for a confidential client by R. W. Beck and Associates. These programs typically experience many of the same problems occurring in other drop-off programs.

One such barrier involves contamination of the collected material with non-specified items. In the HDPE/LDPE bag collection program, notable contaminants include paper receipts, advertising flyers, etc.

Drop-off site signage should inform participants that contaminants such as these must be eliminated in order for the program to be successful.

The major problem with the recovery of these film bags, however, is in finding end-uses for the recovered resins. Heavy mil applications, such as trash bags, are able to use only 5-10% recycled content in product manufacture. If all trash bags, sacks, and liners of heavy mil were to incorporate 5% recycled content, this would provide an annual demand for over 70 million pounds (35,000 tons) of postconsumer material. This 35,000 tons of film represents about two percent of the 2,255,000 tons of LDPE, LLDPE, and HDPE film sold in 1990.

One strategy that may prove useful is the legislation of mandatory recycled content in film packaging, especially in those applications most able to incorporate such material into their manufacturing process. An example of such legislation is discussed below.

Last year (1990), the State of California amended a portion of its Public Resource Code (California SB 2092) to require that as of January 1, 1993, all trash bags of 1 mil or greater thickness sold in California must have at least 10% postconsumer recycled content. As of January 1, 1995, the requirement is extended to trash bags of 0.75 mil or greater thickness and postconsumer recycled material must comprise 30% of the content. "Postconsumer material" is defined in the Public Resource Code and excludes industrial scrap.

Drop-off programs will continue to be increasingly important for the recovery of residential postconsumer film plastics (and in the future, perhaps other plastics) due to the current lack of other cost-effective

methods for collecting consumer packaging film (i.e., curbside and buyback programs are inefficient, inadequate, and inappropriate for providing plastic film collection). Buyback programs are much more appropriate for handling higher value individual plastic containers, such as PET soft-drink bottles. Film presents a difficulty with its high volume to weight ratio, its need for compaction, its various product and resin types, and its low relative value. Drop-off facilities, such as supermarkets, are better able to handle these problems. They normally have a baler on-site, are more likely to attract the desired products (grocery bags and produce bags), and often are subsidizing the bag recycling program as a public relations service.

Similar to a drop-off program, commercial collection of postconsumer plastics requires a business to source separate the recyclable plastic and either (i) place the material in a specially dedicated dumpster for collection or (ii) bale the plastic with an on-site down-stroke baler until sufficient plastics have been inventoried for cost-effective shipment. The latter is usually the case with large industrial production operations which generate significant quantities of recyclable plastics and cardboard. Removal of such items from the firm's solid waste stream is performed in order to defray the costs associated with waste disposal.

The handling and reclaiming residential postconsumer plastics is very costly because of the need to manually separate the different polymers present in the residential plastic stream. Commercial plastics collection appear to be a good source of relatively contaminant-free postconsumer plastics. This is particularly true for film plastics, especially in centralized locations such as commercial and industrial distribution, manufacturing, and production facilities.

Buyback Centers

The third method for collecting recyclable plastics is a buyback center. Buyback centers pay a fee for recyclables delivered to the facility. The recycler then bales the plastic for shipment to a reclaimer. Since recyclers receive only 5 to 10 cents per pound for the baled plastic, the fee usually only amounts to a few cents per pound, providing relatively little incentive to the lower income populous who bring materials to buyback facilities. Buyback centers of this type have participation rates of only 10 to 15 percent. The advantage of this type of program is that it ensures

product quality. Disadvantages include costliness and the fact that very few product/resin types are included.

In bottle bill states, state-approved buyback centers refund a deposit to customers who return plastic containers to the facility. The refund usually amounts to \$0.05 to \$0.10 per container. Bottle bills are normally passed by state legislatures in response to perceptions that plastic bottles create significant litter and are not widely recycled. Ten states have bottle bill legislation. This type of legislation usually applies to carbonated beverage containers and therefore includes PET soft drink bottles. Maine's beverage container deposit law extends to non-carbonated beverages, such as juices, as well. Recovery rates of PET soft drink bottles in the bottle bill states of New York and Oregon were reported to be approximately 58 and 96 percent in 1989.

Critics of deposit legislation argue that bottle bills skim off high value PET bottles and aluminum cans, leaving only the lower value plastics to be collected by the curbside programs. As a result, revenues to support the curbside programs are lower than they would be if the deposit system did not exist. On the other hand, proponents of deposit legislation point out that the great majority of PET soft drink bottles are recovered in states with deposit legislation. Furthermore, the infrastructure for recycling plastic bottles, i.e., handling and reclaiming facilities and stable markets, have been established as the result of deposit legislation.

Future Collection Opportunities

The next five to ten years will hold many changes in the area of plastic collection methods. Mixed waste processing facilities, which receive and process the entire mixed solid waste stream, are one of the newest approaches to recycling. These facilities are multi-million dollar ventures which are only now receiving more attention as the high cost of other less centralized recycling collection alternatives becomes better understood. To the extent mixed waste processing centers become more commonplace, much higher quantities of postconsumer plastics could be recovered. Currently, only about a dozen such facilities are currently planned or in operation. However, these types of processing centers may be plagued by content contamination.

One state-of-the-art facility, Reuters of Florida, has recently opened in Pembroke Pines, Florida. While current operating techniques have proven

effective for removal of PET and HDPE bottles, as well as other recyclables from the waste stream, recovered film has been characterized as fairly contaminated.

Conclusions

- On-board plastic compactors are efficient, economical, and compatible with most collection and processing systems.
- Drop-off programs for all plastics are useful in rural areas and in supermarkets for film plastic collection.
- Bottle deposit legislation may help spur the collection of certain plastic items in a clean, homogeneous stream. Such legislation may also undermine the collection of other plastic products at the expense of other plastic products or collection methods. (PET soft drink bottles collected in such programs leave little revenue-producing plastics to help support curbside programs.) At the same time, deposit legislation has led to the recovery of large amounts of PET soft drink bottles and has been responsible for creating the bottle recycling infrastructure in those states with deposit legislation.
- Mixed waste processing facilities may or may not, in the future, be responsible for the collection of much greater levels of plastics for recycling. However, high levels of contamination of certain items, such as plastic film, have characterized these facilities.

Recommendations

- Curbside collection of residential postconsumer plastics should be chosen by any municipality capable of supporting such a program.
- Commingled collection may or may not be more economical than separated collection depending on the presence of a MRF, applicable MRF charges and the existence of other recycling infrastructure.

- Drop-off (as well as other) collection programs must include appropriate signage (minimal verbiage, pictures of accepted products) and be staffed at certain times, in order to minimize contamination problems. It may be of value to repeat this procedure on a regular basis for new participants or if material quality begins to deteriorate.
- Drop-off (as well as other) collection programs for multi-family residences must include continuous education of new tenants.

CENTRALIZED SORTING OF POSTCONSUMER PLASTICS

Although a certain amount of sorting takes place at the point of collection, there is a continued need for additional material upgrading during the handling and processing phases of recovery. The following discussion addresses the technical issues related to centralized sorting of postconsumer plastic. This sorting can take place at several points along the handling and processing chain including the MRF, a postconsumer plastic facility designed specifically to sort and grind baled plastic (herein referred to as a "PRF"), and the postconsumer plastic reclamation facility.

Sorting Postconsumer Plastic at a MRF or Recycling Facility

Depending on factors such as ease of identification, value of resin, availability of resin, and ease of sorting, one of the following streams of postconsumer plastics may be targeted for recovery.

- Soft drink bottles;
- Soft drink and milk bottles;
- Soft drink, milk, and laundry detergent bottles;
- All plastic bottles SPI coded "1" and "2";
- All plastic bottles;
- All plastic rigid containers; or
- All plastic.

Most postconsumer plastic collection programs established during the 1980's originally only targeted PET soft drink bottles for recovery due to the availability of established markets, primarily as a result of the widespread collection of PET soft drink bottles from bottle deposit states. As stated earlier in Section 2, PET soft drink bottles collected as part of such early curbside collection programs produced a ready supply of relatively clean, high value recyclable plastic requiring relatively minimal sorting costs.

With the growth of markets for other postconsumer HDPE Products, such as piping and household chemical bottles, the collection of postconsumer HDPE milk and laundry detergent bottles became commonplace occurrence. Furthermore, the development of the Dupont/Waste Management joint venture ("PRA" which is now solely owned by DuPont), originally encouraged the collection of all SPI bottles coded "1" and "2" by many programs across the country. PRA has now restricted their purchases to PET soft drink bottles and HDPE milk and water jugs.

Moreover, the ability of certain plastic lumber manufacturers to accept a wide array of plastic packaging has provided some communities with the opportunity to collect all plastic rigid containers or in some instances, all postconsumer plastic. (It should be noted that certain plastic lumber producers do not accept PVC or PS.) Yet, the rapid expansion of postconsumer plastic collection has out-paced the ability to develop a cost-effective infrastructure for sorting the recovered postconsumer plastic.

Selection of Plastics To Be Sorted

Depending upon the stream of postconsumer plastic selected for collection by a community, the facility charged with handling the collected plastic must then select the level of sorting that is most economically advantageous to perform. The facility operator will base the decision of whether to separate and process the plastic by individual resin type based on the incremental cost associated with sorting, processing, and shipping the individually sorted resin grades versus the incremental income generated from the sale of the upgraded material.

In most instances, MRFs and more traditional recycling operations ("Plastic Handling Facilities") have demonstrated the ability to perform simple plastic sorts such as the separation of PET soft drink, and HDPE milk and

laundry detergent bottles, either commingled or as individual streams. Yet, with many collection programs' definition of recoverable plastics expanded to include an ever increasing variety of plastic bottles/containers, the level of sophistication required to sort plastics has greatly increased, without a commensurate increase in the level of education on the part of the plastic handler regarding the appropriate plastic products to recover and methods for upgrading the stream to maximize revenue.

As a result, the quality of the sorted plastic has suffered and profit margins for plastic handling have come under considerable pressure. This is particularly important since, due to the current weak market conditions for recycled plastic (See Section 2 - "Markets"), only the highest quality sorted plastic materials provide a reasonable return to the plastic handler.

Limitations to Manual Sorting

The squeeze on plastic handler profits is a result, not only in the drop in virgin prices and lack of end-market demand, but also a result of the limitations of hand sorting currently marketable plastics. This problem became worse when programs' expanded definition of plastics for collection to include all 1's and 2's, although markets such as PRA that originally requested that all 1's and 2's be collected have since narrowed that statement to include only PET soft drink and HDPE milk/juice/water and laundry bottles. As a result, many plastic handlers are faced with determining which plastics are actually recoverable based on current market demand.

For instance, it is difficult for a sorter at a plastic handling facility to identify recyclable plastic bottles coded "1" since look-alike bottles such as the Wesson Oil bottle (manufactured from PET in some instances and PVC in others) confuse sorters, causing sorting errors. Although the PET Wesson Oil bottle is coded "1" and the PVC bottle is coded "3", the sorter does not have time to check the bottle's coding due to the speed at which the plastic bottles travel along the sorting conveyor belt. In such instances, a PVC bottle may be sorted into a bunker of PET bottles, thereby rendering the entire load virtually unmarketable. As mentioned earlier in this report, one PVC bottle in 10,000 PET bottles ruins the quality of the end-product produced from the recycled PET.

In addition, many custom PET bottles such as Gatorade, and Folgers bottles would be otherwise recoverable except for the PVC cap liner or PS closures on these bottles, respectively.

These particular barriers could be overcome by redesigning bottles to eliminate incompatible parts or by removing all caps and closures prior to shipping the material to market. All PET soft drink bottles could be positively sorted out initially, with the remaining clear bottles consisting of custom PET and PVC containers being sorted separately. A positive sort of the remaining clear bottle stream could then be performed, focusing on sorting only those bottles which are clearly recognized as being either PET or PVC. Any caps and closures would be removed from the bottles at this time. All remaining bottles would pass off the end of the conveyor belt for later sorting or disposal.

It should be noted that, due to the current low demand for recycled PET, many PET plastic reclaimers are hesitant about purchasing postconsumer PET other than high quality soft drink bottle material. Yet, it should be noted that certain boutique type handling/intermediate processing operations such as South Bronx 2000 Local Development Corporation in Bronx, New York and North American Plastic Recycling Corporation in Fort Edward, New York are sorting custom PET bottles successfully. The key to the widespread implementation of this type of sorting system will hinge upon (i) the production of a consistently high quality product, either in baled or flaked form and (ii) the establishment of a close working relationship with a plastics reclaimer willing to accept such high quality material.

In addition to PET custom bottles, many HDPE containers coded "2" are considered to be contaminants by plastics reclaimers. These materials include injection-molded (in contrast to blow-molded) HDPE containers such as baby wipes and butter tubs which are coded "2". Again, this adds to the level of confusion on the part of the sorter and jeopardizes the quality of the material sorted.

Methods for overcoming this barrier would include redesigning these containers, providing specific educational literature to program participants emphasizing the collection of exclusively bottles rather than all containers, focusing upon the bottles' narrow neck as a characteristic that differentiates them from other containers such as tubs and jars. In instances where participants accidentally set out tubs and jars, curbside

collectors and plastic handlers must be informed that only HDPE narrow neck bottles should be segregated for recovery.

Other resins such as PP, PS, PVC, and LDPE will need to be addressed on a case-by-case basis. In general, these four resins represented less than 15 percent of all plastic bottles manufactured in Calendar Year 1990 (primarily PVC, PP, and LDPE). As mentioned previously, PVC bottles could be recovered when sorting clear bottles after the removal of the clear PET soft drink bottle material. Polypropylene bottles, primarily syrup and ketchup bottles, could also be separated, potentially by one sorter targeting PVC bottles and any PET and HDPE bottles missed earlier on the sorting line. LDPE bottles are very infrequent (primarily mustard jars) and would likely be allowed to pass off the belt in all but the most aggressive sorting programs.

In instances where plastic lumber markets are available, plastic tailings such as any miscellaneous non-specified bottles or containers could be baled and shipped for recovery. The cost effectiveness of sorting the current "second tier" of plastic bottles manufactured from custom PET, PVC, PP, and LDPE will likely be based on the speed at which a sorter can physically segregate each stream of bottles by resin type and the sorter's ability to produce a relatively high quality pure product for recovery. The following discussion addresses the manual sorting rates for plastic bottles based on field experience at several MRF's and plastics reclaiming facilities across the country.

Manual Sorting Rates

Based on a survey performed by The Council For Solid Waste Solutions, of several MRF's sorting plastics across the United States performed during Spring, 1990, sorting rates for separating whole postconsumer plastic bottles, primarily from a stream of mixed recyclables varied greatly, from 73 to 554 pounds per hour as shown in Table 3-7. In this analysis, sorting consisted of the separation of PET soft drink and HDPE milk, juice, and water bottles.

The sorting rates reflected in Table 3-7 differ significantly due to the handling techniques used in each of the facilities listed. The sorting rate was determined, not by the speed of the sorter, but by the speed of the conveyor, the quantity of plastic on the belt, and the number of different materials sorted by each sorter. In certain instances, sorters were required

Table 3-7
Manual Sorting Rates

MRF	RATE (lb/hr/sorter)
Seattle (N), Washington	73
Seattle (S), Washington	74
Peekskill, New York	83
Odense, Denmark	84
Somerset, New Jersey	96
Toronto, Ontario	157
Charlotte, North Carolina	170
Eden Prairie, Minnesota	467
Johnston, Rhode Island	525
Philadelphia, Pennsylvania	554

Source: "Collection Method Profiles and Material Recovery Facilities Assessment" Proposed for The Council For Solid Waste Solutions by Resource Integration Systems, Ltd., July 1990

to positively sort plastics from a stream consisting solely of plastic bottles and aluminum cans (Philadelphia), resulting in a relatively high sorting speed. In other cases, sorters were required to sort more than plastic, and as a result, the overall rate of plastics separation declined.

Field experience with hand sorting has shown that optimal sorting rates for most recyclable packaging approaches approximately one bottle/container per second for any sustainable period of time. Applying this fact to the removal of a typical plastic HDPE milk bottle weighing approximately 0.14 lb or a two liter PET soft drink bottle weighing approximately 0.17 lb, a sorter operating at a rate of one bottle a second could potentially sort plastic at a rate of 400 to 600 pounds per hour. Based on the results of the Council study, it would be reasonable to conclude that the optimal hand sorting speed for plastic bottles in a MRF setting approaches 400 to 500 pounds per hour.

The Philadelphia MRF evaluated as part of the Council analysis best represents a case where hand sorting speed is optimized. As shown in Table 3-7, mixed HDPE and PET plastic is separated out at a rate of approximately 550 pounds per hour. At the time of the Council study,

plastic bottles and aluminum cans were conveyed to the Facility's sorting area. The plastic was removed from an elevated conveyor by hand and tossed into an open top trailer below.

It should be noted that the actual rate of sorting plastic will depend upon several factors including the number and types of plastic containers to be segregated, the containers' color and size, not to mention problems associated with look-alike bottles such as the Wesson Oil container. As would be expected, smaller containers are more difficult to identify in the mix, thereby reducing the speed at which the plastic can effectively be removed from the belt. Moreover, the sorting rate will also be lower if the sorter is requested to separate the incoming plastic by resin type rather than as a commingled stream. When plastic is compacted on the collection vehicle, identification of individual resin types becomes more difficult, reducing the rate at which the plastic bottles can be effectively separated due to the flattening and clustering/interlocking of the bottles.

Sorting compacted plastic by resin type is even more of a concern when sorting plastic bottles at a plastic reclaimer's facility, again due to flattening and clustering of the bottles. Based on an informal survey of several plastic reclamation facilities, sorting rates for debaled mixed plastic bottles (either milk/soft drink/laundry or all bottle streams) range from approximately 250 to 300 pounds per hour depending upon the number of discrete resin separations performed and the actual layout of the facility. This assumes that an incoming bale of (30" x 40" x 60") weighs no greater than 800 pounds in order to minimize clustering and potential fusion of bottles which reduces sorter productivity greatly if not destroying the physical properties of the bottles altogether.

It should be noted that the reclamation facilities remove all caps and closures during separation which improves the quality of the material before grinding, although it slows the sorting process moderately. Yet, it has been found that such upgrading of materials, particularly when ground/flaked, can increase the net revenue from plastic handling. This is discussed later in this section.

Automated Separation

Automated separation consists of the use of automated equipment to reduce the level of manual effort required to sort the incoming stream of recyclable containers entering a MRF. The equipment uses the sizes,

densities and shapes of the various containers to differentiate the materials and thereby segregate the materials into pure streams. The Johnston, Rhode Island MRF's use of an inclined conveyor and rotating brush system is the trademark of the Bezner system, whereas the use of an air classifier that blows or lifts plastic from a commingled stream are examples of other automated sorting equipment.

A series of vibrating screens and trommels can also be used to separate recyclables of varying sizes. For instance, a vibrating bar screen is used in the Johnston MRF to sort a majority of the HDPE milk jugs and PET soft drink bottles from the aluminum cans. The few remaining plastic HDPE jugs and PET bottles are separated from the aluminum can stream through the use of an eddy current.

Yet, it should be noted that trommels and screens rely specifically on the varying sizes of the containers in order to separate the materials into homogenous streams. As a result, it is particularly difficult to separate recyclables of similar size. This is particularly the case with regards to segregation of aluminum cans from many of the smaller plastic bottles such as 16-ounce soft drink, shampoo, and syrup bottles. In instances where many of the plastic containers are similar in size to the glass, aluminum, and steel bottles and cans, several trommels and screens may be necessary to effectively separate the materials, which increases the cost to process the materials.

Eddy currents are another common method for separating various recyclables, particularly aluminum from plastics. The basic components of the eddy current equipment consists of an external drum, an internal permanent magnetic rotor, and a drive and belt conveyor. The eddy current produces a magnetic charge that is transferred to a passing aluminum can. The cans are then passed in front of a magnet at which time the cans are repelled by the magnet off the conveyor. The remaining plastic stream continues on the conveyor belt unaffected.

The one common thread to all the more traditional automated sorting equipment mentioned above focuses on the need to have the plastic containers entering the plastic handling facility in its original shape. As a result, on-board compaction of the plastic during collection or the advocacy of NAPCOR's "Step On It!" campaign can greatly impact the effectiveness of such equipment if such collection program elements are not factored into the design of the plastics handling facility initially.

Emerging Automated Bottle/Chip Sorting Technologies

Several newly emerging automated separation technologies are currently being tested or are nearly reaching commercial availability and, if successful, could substantially reduce the cost of separating postconsumer plastic by resin and/or color. Although several strategies are being used to advance the automated separation of postconsumer plastic containers, all of the proposed technologies tend to fall into one of two categories: whole bottle (macrosorting) or chip separation (microsorting). The following discussion outlines several of these latest attempts to produce a commercially viable system for the separation of postconsumer plastics.

MACROSORTING TECHNOLOGIES

Photoelectric Sensors - Center for Plastics Recycling Research (CPRR)

Acceptable Waste Stream

This sorting technology is ideal for a mixed resin stream consisting of clear and colored PET and HDPE. Three sorts are performed using photoelectric sensors: clear PET, green PET, and translucent HDPE. After these three fractions have been sorted, the remaining component, opaque HDPE, is conveyed off the end of the line.

Description of Technology

An automatic feed mechanism sends one bottle at a time, lying down, through the detection device. This device sends three beams of light at varying frequencies through each container to a detector which measures the amount of light energy received. The different resin types and colors absorb varying amounts of light energy, so that the targeted resin, when detected, is blasted with a jet of air, off the conveyor belt. The sensors first remove the clear PET, then green PET, and finally translucent HDPE, leaving opaque HDPE for the end of the line.

Unfortunately, no real plastics waste stream will consist of only the four above-mentioned resins. To some degree, other resins will be present. In order to overcome contamination of one specific resin, PVC, CPRR has also added X-ray, fluorescence systems similar to that discussed below. This type of method for PVC removal is a distinct technology which is also discussed below. If other non-targeted resins such as LDPE, PP, and PS are present in the stream they will be sorted out with the HDPE. If the non-targeted resin is translucent it will sort with the translucent HDPE, otherwise it will be sent off the end of the line with the opaque HDPE. The presence of these non-targeted resins mixed with the HDPE does not necessarily ruin the HDPE. A manual sort of the remaining bottles can be performed or, in some cases, mixing of the resins has been cited as adding tensile strength to the HDPE.

Some degree of crushing of the bottles is allowable with this system. Until recently, questions remained as to whether the system could handle crushed bottles from baled materials. In response, CPRR has developed another system with different detectors.

The entire system with PVC detector, automatic feeder and conveyors is estimated to cost less than \$80,000. The model can process 1,000 pounds per hour or approximately 2.5 bottles per second (9 bottles per pound).

Market Availability

A full-scale model was completed earlier in 1991. This system is not in commercial use.

X-Ray Fluorescence to Remove PVC - National Recovery Technologies, Inc. (NRT)

Acceptable Waste Stream

A stream of any number of mixed resin types is acceptable for sorting using this technology. Only one sort is performed which targets PVC to be ejected from the stream.

Description of Technology

Polyvinyl chloride differs from any other resin type in that its structure contains chlorine. To identify a PVC container this technology implements

X-ray fluorescence to detect the chlorine atom. Once a PVC bottle has been detected, a jet of air ejects it from the stream.

This system, costing approximately \$125,000 plus a monthly leasing fee, is capable of processing 4,000 pounds per hour for PVC bottle separation or approximately 10 bottles per second (9 bottles per pound).

Market Availability

This system is commercially available. There are six or seven in use. The system cannot detect bottles with PVC cap liners, which greatly reduces its effectiveness based on the industry's current standard of no PVC contamination. Moreover, the NRT system does not address the separation of other resins such as HDPE, PET, and PP. Therefore, additional manual sorting would still need to be performed.

MICROSORTING TECHNOLOGIES

Color Separation - Plastic Resin Separation Specialists, Inc. (PSS)

Acceptable Waste Stream

This technology can accept greatly varied streams of unwashed granulated material.

Description of Technology

The technology in this system of sorting is proprietary. A precise description is, therefore, not possible, yet it can be said that the technology does not use water or chemical solvents. Air is used to convey the granulated material and also to remove the fine powdery particles from the bigger flakes. The powdery particles, known as fines, can constitute up to 2% of the flake material, a significant contaminant if not of the same resin. Other materials which have been removed by PSS from flake batches include: dirt, wood chips, ABS from polycarbonate, and clear from colored resins. The PSS system is capable of sorting HDPE into clear, green, red, and blue categories. PET can be separated into clear and green fractions. PSS claims that its technology is not limited to certain materials, sizes or color types. The only apparent limitation for the color separation is for

resins of similar colors (i.e., clear on clear cannot be separated), so that clear PET is not able to be sorted from PVC through their color separation process.

The sorting is done in nine different stages on batches of ground material, as opposed to a continuous flow system. Color separation is one of these stages.

Market Availability

Processing using this technology is done both in-house by PSS or may be licensed to other companies which pay a royalty per pound to PSS. The technology is not patented for fear that it could be mimicked easily.

Cost of processing ranges from 10 to 20 cents per pound if the material is sent to PSS for separation which would price most commodity type resins out of the market for this separation technique. The price is decided after PSS has seen a sample of the contaminated batch. To purchase the system, costs range from \$300,000 for a small system to \$500,000 for mid-sized, to \$800,000, to \$1,000,000 for a large system. The rate of processing for a large system is estimated at 5,000 pounds per hour or approximately 12 to 13 bottles per second.⁷

Supercritical Fluids - University of Pittsburgh

Acceptable Waste Stream

This system is not limited to certain mixtures of materials. It is a microsorting system accepting shredded or ground plastic of any variation of resin or color type. The incoming plastic stream should be washed prior to sorting.

Description of Technology

This technology is based on differences in the density of different resins to sink and float certain fractions of the plastic mix. Water is a fluid which is commonly employed in sink/float technologies to sort PET from HDPE due to the fact that PET sinks and HDPE floats. This technology

⁷ PSS® and *Plastics News*, May 13, 1991, p. 12.

replaces water with carbon dioxide (CO₂) and CO₂-based mixtures at temperatures and pressures above their critical values, hence the name supercritical fluid. Using supercritical fluids allows for more precise sorting due to the fact that the density of the medium, the CO₂-based mixture, itself, can be controlled to within ± 0.001 g/cm³. The density is set so that the heaviest fraction settles out and is removed. Then the density is adjusted by changing the pressure so that the next heaviest fraction will sink. Using this supercritical fluids allows HDPE to be separated from LDPE and PET to be sorted from PVC. The precision of control allows for not only the efficient sorting of resin types, but also of certain colored resins. Color sorting is possible due to the fact that certain pigmentation in the resins causes a large enough variation in density for the supercritical fluid to differentiate. However, not all colors can be separated. For example, blue HDPE can be separated from orange, but green cannot be sorted from black HDPE.

Another advantage to using CO₂ is that its viscosity is 1/10 that of water which allows for much more rapid settling of the particles.

The cost involved for a full-scale version of this system has not yet been determined.

Market Availability

A laboratory scale model has been completed. However a full-scale version has not. A date for commercial availability is undetermined at this time, due to the fact that adaptations for continuous flow versus batch feed need to be made for the full-scale model. Presently, the laboratory model sorts batches weighing only one pound.

Froth Flotation - Devtech Labs, Amherst, NH; Recover Processes, Inc.; Park City, Utah; and Colorado School of Mines, Golden, CO

Acceptable Waste Stream

Work on this technology is progressing towards being able to accept a mixed resin stream in granulated form. In some cases pre-washing is required. However, in other cases, the sorting method, itself, washes the material.

Description of Technology

This technology has existed for years in the mining industry, but is just recently being adopted for use with postconsumer plastics. The granulated plastics are introduced into a vat containing chemical surfactants which coat or react with the surface of the targeted resin. Air bubbles, put into the bottom of the tank, will selectively adhere to the targeted resin. This resin will float and be skimmed off the surface of the liquid medium.

In the instance where the surfactant is merely coating and not reacting with the surface of the resin a simple cleaning step will leave the targeted resin unaffected. However, when the surfactant being used reacts with the surface of the flakes, the quality of that resin will be affected. Depending upon the quality specifications of the intended end use, that resin may or may not be recoverable.

The present stage of this technology can sort PET from PVC and aims at being able to sort a mixture of the six postconsumer resin categories.

Market Availability

The system from Devtech Labs is not yet commercially available, but may be ready for commercial use within one year. Recovery Processes, Inc. will license their technology⁸. Colorado School of Mines has exhausted its funding and is therefore at a standstill with this sorting method.

ECONOMICS OF SORTING

This section attempts to compare the costs of each of the manual and automated sorting technologies reviewed above. Due to the preliminary nature of many of the automated separation technologies currently under development, operating and capital cost data are not available for review at this time.

Manual Sorting Costs

Based on a Council For Solid Waste Solutions MRF study performed during 1990, it was estimated that the typical labor cost for hand sorting

⁸ *Plastics News*, April 29, 1991.

whole plastic bottles at a plastic handling facility amounted to approximately 1.9 cents per pound as shown in Table 3-7. This was based on a typical hourly rate of \$10.00 for sorting labor and a handling rate of approximately 525 lb/hr/sorter. Based on the analysis, a graph plotting the throughput of the proposed facility versus the average cost for manual sorting the plastic bottles was developed as shown in Figure 3-2. As can be seen in Figure 3-2, manual separation costs fluctuate such that a sorter's hand rate is optimized at approximately 500 lb/hr of plastic bottles and thereafter requires an additional sorter. This function also repeats itself at the 1,000 lb/hr level.

Based on previous experience of R.W. Beck, the rate of 525 lb/hr/sorter likely reflects only the most optimistic case for manual sorting. A more likely scenario would have a typical hand sorter segregating plastic bottles at a rate of approximately 400 lbs/hr/sorter for a sorting cost of approximately 2.5 cents per pound. It should be noted that the all cost figures reflected herein are based on (i) an average labor rate and (ii) the methods used for hand sorting plastic bottles, which will vary from location to location.

Air Classifier Costs

Air classifiers use air jets to separate the light fraction of the recyclables stream (e.g., plastic from the heavier fraction in such as glass bottles). This equipment is reported to handle between 4 and 8 tons per hour of commingled recyclables at a capital cost of \$24,000 to \$30,000. The cost analysis was based on several key assumptions:

- Incoming material is 50% glass, 30% plastic, and 20% aluminum by weight
- 8 hour shifts over 250 days per year
- Equipment amortized over 7 years at 10% per year
- Equipment operating cost at 2.5% of capital cost
- No labor requirements or installation costs.

Figure 3-2 provides a graphical depiction of this cost function. Based on this cost analysis, the cost of automated separation through the use of air classification equipment tends to approach 1 cent per pound of plastic bottles sorted.

It should be noted that it would be extremely difficult to readily separate potential problem bottles such as PET custom bottles with PVC cap liners or the look-alike Wesson Oil bottles because these products would in many instances possess the same physical features as other bottles in the stream. Moreover, since the air classification systems rely on the plastic bottles' light-weight and relatively large size to eject the plastic bottles from the overall recyclables stream, compaction of plastics during collection would need to be prohibited, and therefore increasing overall collection costs. Based on the fact that (i) hand separation of certain plastics would likely be required prior to marketing the materials, and (ii) the need to collect plastics uncompacted, it is not clear whether air classification would continue to hold the cost advantage over manual separation reflected in Figure 3-2.

Eddy Current Separator and Trommel Costs

A similar cost analysis was performed as part of the Council study for the use of eddy current separators and trommels for automatically separating plastic bottles from the mixed recyclables stream. The capital cost of an eddy current system typically exceeds \$100,000, depending on the throughput of the equipment. In general eddy current separators have the ability to handle anywhere from 1 to 6 tons of recyclables per hour.

Trommel screens vary greatly in size and throughput capacity (from less than one ton/hr up to 20 tons/hr) with costs as high as \$150,000 and over. Based on the Council analysis, a trommel screen for use in separating plastic bottles from aluminum would cost approximately \$30,000 and could handle approximately one ton per hour of mixed aluminum and plastic containers.

The cost analyses for the eddy current and trommel screen systems were based on several key assumptions as shown below:

- Incoming material is 60% plastic and 40% aluminum by weight
- 8 hour shifts over 250 days per year
- Equipment amortized over 7 years at 10% per year
- \$10 per hour labor, including benefits

- Operating costs at 5% of capital costs plus \$1,000/yr for parts.

Figure 3-2 provides a graphical depiction of the cost functions for the use of eddy current and trommel screen separation systems. Based on this cost analysis, the cost of automated separation through the use of both eddy current and trommel screen separation tends to approach \$0.02/lb of plastic bottles sorted.

Like the air classifier system, it would be extremely difficult to separate potential problem plastic bottles such as PET custom bottles with PVC cap liners or the look-alike Wesson Oil bottles using eddy current or trommel screen separators due to the similar physical features of these bottles to other plastic bottles in the incoming stream of recyclables. Based on the fact that hand separation of these materials would likely be required prior to marketing materials, it is likely that the cost of separation using eddy currents or trommel screens would be higher than manual separation.

Methods for Improving Plastic Handling Economics

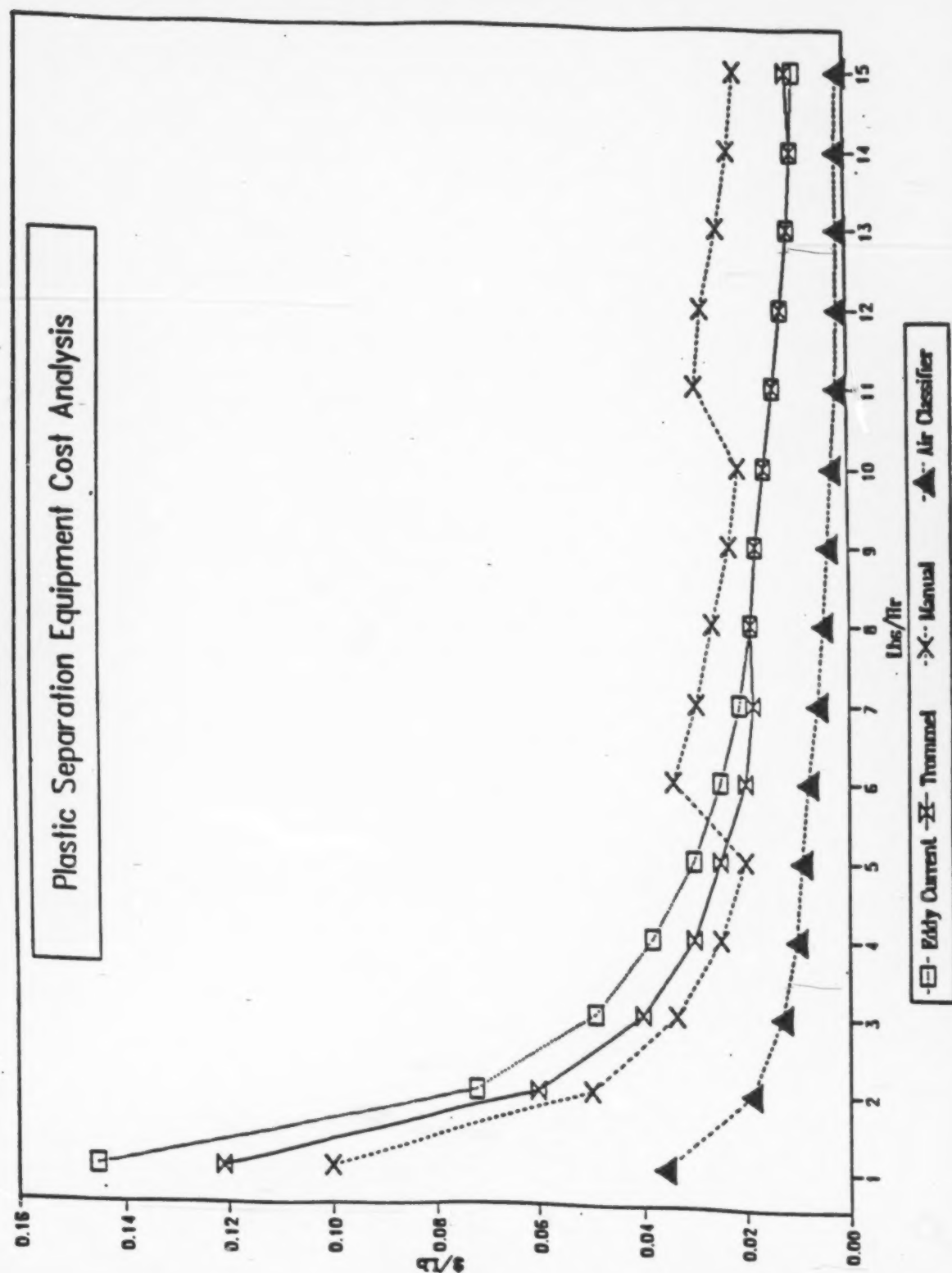
As mentioned earlier in Section 2, the true test for postconsumer plastics recycling will be based on the following objectives: (i) improving the cost effectiveness of handling and processing postconsumer plastic to make the recycled flake or pellet more competitive with virgin, wide-spec and industrial scrap resins, and (ii) establishing consistent end-markets for the purchase of the recycled flake or pellet.

One method to improve cost-effectiveness would be to eliminate certain unnecessary handling procedures in preparing plastic for reclamation. The most glaring example of this is the practice of baling plastic for shipment to the plastic reclaimer. In doing so, the plastic handler is not only adding unnecessary expense to the handling process for baling and later debaling of the material, but also for two manual plastic sorts - one at the handling facility and a second at the plastic reclaimer's operation.

A preliminary sort at the MRF or plastic handling facility removes most contaminants prior to baling. A second sort at the reclamation facility is done after debaling to remove residual waste along with caps and closures before grinding.

Plastic reclaimers generally require the level of contamination present in the delivered bales to be less than 3 percent of the bale's weight. With moderate additional effort on the part of certain MRFs and plastic

Figure 3-2



handling facilities, both sorting routines could be performed while the plastic is still loose, eliminating the need for baling and debaling, transportation of contaminants, eliminating problems associated with bottle clustering due to the baling process, and greatly improving the revenue stream to the plastic handling facility. MRFs and handling facilities with a sufficiently long sorting line and bunker space and capital for grinders could handle such a task if operators and sorters are given adequate training. For MRFs and handling facilities which were not equipped or capitalized to accomplish this shift in operation, the change would require considerable investment. It might also involve a disruption in operations while building equipment modifications were taking place.

The economic incentive for grinding bottles in the handling facility is suggested below. Table 3-8 shows recent market prices for baled and flaked postconsumer resins.

Table 3-8
Comparative Prices for Baled and Flaked Material

Material	Market Price (11/91) (\$/lb)
Bales of mixed PET and HDPE	\$0.04 to \$0.07
Clear PET flake ⁽¹⁾	\$0.15
Green PET flake ⁽¹⁾	\$0.09
Clear HDPE flake ⁽²⁾	\$0.15
Pigmented HDPE flake ⁽³⁾	\$0.11
PVC flake ⁽⁴⁾	\$0.15
PP flake ⁽⁴⁾	\$0.11

(1) Both custom bottles and soft drink bottles; assumes all caps and PVC bottles are removed prior to grinding.

(2) Milk and water jugs.

(3) Household chemical bottles.

(4) Limited markets at the present time.

Source: R. W. Beck and Associates

It is important to note that the economics described here assume that PET and PVC are fully segregated. The difficulty of separating PET and PVC has already been discussed.

Since a majority of the postconsumer plastic material consists of PET soft drink and HDPE milk/juice/water and laundry detergent bottles, the weighted average price for hand sorting and grinding the collected postconsumer plastics into individual resin streams based on these recent prices would approach approximately \$0.13/lb. Consolidating grinding operations at a single handling facility could improve the cash flow as shown in Table 3-9. It should be noted that prices for both baled and flaked postconsumer plastics have been in a general downtrend throughout 1991 due to a protracted U.S. recession and an overcapacity in virgin resin production. Therefore, the estimates here represent a snapshot of prices as of September 1991 and will vary with economic conditions and industry supply and demand. The intent of this analysis is to reflect the increase of net revenue potentially available to the handler, assuming the grinding operation is performed effectively and reclaimers accept this procedure.

Assuming that reclaimers would pay a weighted average price of \$0.13/lb for the ground plastic, avoided baling costs of approximately \$0.015/lb, additional sorting cost of approximately \$0.02/lb, grinding cost of approximately \$0.05/lb minus the revenue from selling the mixed bales of plastic at approximately \$0.06/lb (focusing on the fact that the bales could include only PET soft drink and HDPE milk/juice/ water and laundry detergent bottles), conservatively, a net increase in income of \$0.015/lb or \$30 per ton of plastics could be realized.⁹

This is based on the assumption that manual sorting takes place at a rate of 500/lb/hr/sorter based on baling mixed PET soft drink and HDPE milk/juice/water and laundry bottles. It is also assumed that 250/lb/hr/sorter, manual sorters could separate into individual resin

⁹ It should be clearly noted the prices reflected herein are based on several industry quotes as of September 1991 and are meant to show the relative differences in prices for baled versus flaked post-consumer plastics. Actual market prices for post-consumer plastics vary greatly over time. Therefore, collection and processing decisions should be based on current information available from industry representatives.

Table 3-9
Revenue Comparison of Baling versus Grinding
at a Plastic Handling Facility ⁽¹⁾
 (All values in dollars/lb of plastic handled.)

Revenue	Baling Operation	Grinding Operation
Gross Revenue ⁽²⁾	\$0.06	\$0.13
Baling Cost ⁽³⁾	\$0.015	-
Grinding Cost ⁽³⁾	-	\$0.05
Sorting Cost ⁽⁴⁾	\$0.02	\$0.04
NET REVENUE	\$0.025	\$0.04

⁽¹⁾ A plastic handling facility refers to either a MRF or a more traditional recycling operation. This analysis does not take into consideration fixed costs. Estimates of September 1991.

⁽²⁾ Based on average current market prices for a mixed stream of baled PET soda and HDPE milk/juice/water and laundry bottles and a weighted average price for ground PCR separated by resin and color, respectively.

⁽³⁾ Based on a survey of post-consumer plastics handlers and reclaimers performed by R. W. Beck and Associates for The Council For Solid Waste Solutions, 1990.

⁽⁴⁾ Assumes sorting speeds of 500 lb/hr and 250 lb/hr for the baling and grinding operations, respectively, and a labor rate of \$10.00/hour.

streams. It is likely that the actual sorting rate for producing mixed bales may be lower than 500/lb/hr/sorter, while sorting rates for separating mixed plastic bottles into individual resin streams could approach 300/lb/hr/sorter. If these sorting rates were applied to the analysis shown in Table 3-8, the increase in net income generated from a sort and grind operation could approach \$0.025 or \$50 per ton of plastics separated.

Widespread implementation of this type of sorting system would hinge upon (i) the production of a consistently high quality flaked product, and (ii) the establishment of a close working relationship with a plastics reclaimer willing to accept such high quality material. As mentioned earlier, certain plastic handling operations such as South Bronx 2000 Local Development Corporation in Bronx, New York, North American Plastic Recycling Corporation in Fort Edward, New York, Miami Recycles in Miami, Florida, and River Recycling in Lady Lake, Florida are currently performing such sorting and grinding successfully.

The development of such working relationships could be promoted by NERC in order to provide greater economic opportunities for plastic

handlers throughout the Northeast. This could be accomplished by NERC's convening MRF operators and handlers to explore the possibility of switching to a single sort/flaking system. The key to making this strategy successful will be the coordination of efforts of the plastic handler and reclaimer in understanding the quality standards required and methods for cost effectively handling the material. Section 2 contains a list of handlers and reclaimers located in the Northeast that could be targeted for such discussions.

One caveat to this approach would be that if whole bottle automated sorting technology, rather than flake sorting, becomes the preferred method for resin segregation in the future, then handlers could be pressured to switch back to baling mixed plastic for sale to a centralized automated sorting facility. However, this assumes that whole bottle sorting will become commercially available and cost-effective over other automated sorting techniques, which is unproven at this time.

CONCLUSIONS

Current centralized sorting techniques are almost exclusively performed with the use of manual labor. It is unlikely that extensive automated sorting will become commercially available for at least the next 12-18 months.

Until such time, improving the cost effectiveness of hand sorting will rely upon the development of clear educational literature for collection program participants emphasizing the product types or physical characteristics of the bottles to reduce contamination levels before reaching the plastic handler's facility. Moreover, eliminating certain unnecessary handling procedures such as baling and debaling and improved sorting and the addition of the grinding activity at the MRF/plastic handling facility (subject to reclaimer acceptance of ground material) could not only improve the net profit margin of these facilities, but could also reduce the cost associated with the transportation of waste materials invariably found in mixed bales.

RECOMMENDATIONS

- Encourage and/or assist in the development of carefully designed educational literature to increase public under-

standing of which plastic products are currently recyclable. The literature should focus on specific types of product for recovery (milk, soft drink, laundry, plastic bags) and/or physical characteristics of the materials to be collected that are easily recognizable (e.g., narrow neck bottles). The literature should also stress the removal of caps, rinsing, and stepping the plastic bottles for volume reduction before collection.

- Develop educational literature on a technical operator's program to educate MRF and other plastic handling facility operators and ultimately their sorting line crew as to the appropriate plastics to be collected and methods for most effectively hand-sorting plastic [i.e., remove dominant resins first (PET soft drink, HDPE milk) followed by HDPE laundry (light/dark cut sort), clear bottles into PET and PVC, etc.)]
- Attempt to establish grinding operations at the handling facility in order to improve the MRF's or other plastic handling facility's net income stream from plastic. It will be extremely important to establish a close working relationship with one or more plastic reclaimers willing to accept the ground material prior to implementation.
- Continue to monitor the commercialization of automated sorting technology. The advent of such technology will likely dictate the future course of residential postconsumer plastic bottle recovery efforts.

Section 4

END-USE MARKETS

INTRODUCTION

This section discusses the demand for recycled plastic by current end-use markets. No attempt has been made to assess the potential market for products resulting from experimental technologies, such as hydrolysis, glycolysis, methanolysis, and other depolymerization technologies.

This discussion of the demand for recycled plastic by end-use markets begins with an overview of the market for plastic products. The number and types of plastic products being manufactured in the United States, the number of firms engaged in manufacturing these products, and the dollar value of these products are reported. Attempts to identify the capacities of manufacturing facilities and the resin consumption by manufacturers were not successful because this information is regarded as proprietary by most firms.

Because the number of plastic products is so large and varied, a discussion of all products manufactured from plastic is beyond the scope of this Report. Therefore, discussion of specific products is presented using three categories based on current level of recycled content and the resin specifications, as well as a more general discussion of the barriers to increasing the use of recycled plastic and some strategies for overcoming these barriers.

OVERVIEW

In January of 1991, Modern Plastic reported that U.S. plastics sales (including exports) were more than 61 billion pounds in 1990. Although determining the number of plastic products depends on how a "product" is defined, it is estimated that roughly 20,000 plastic products are manufactured in the United States. By far, the two largest product categories, in terms of resin sales for 1990, were packaging, with more than 24 percent of total sales, and building and construction materials, with more than 19 percent of total sales.

Section 4

Of the seven resins under discussion for this Report, a total of 45 billion pounds were sold. Again, the major product categories for these resins were packaging and building and construction materials. Packaging accounted for about 29 percent of the sale of the seven resins; building and construction materials accounted for almost 14 percent. Table 4-1 shows the sales of plastic by major market and resin type.

Table 4-1
Plastic Resin Sales by Major Market for 1990
(shown in millions of pounds)

Market	PVC	PP	HDPE	LDPE	PS	PET	TOTAL
Packaging	762	1,505	4,204	4,886	1,723	1,225	14,305
Building	5,434	32	562	334	379	0	6,741
Electronics	590	47	164	412	493	0	1,706
Housewares	140	272	233	440	248	0	1,333
Transportation	280	314 ^[1]	206 ^[2]	0	0	0	800
Toys	37	48	154	170	214	0	623
Appliances	119	185	20	0	220	0	544
Furniture	94	105	22	0	92	0	313
TOTAL	7,456	2,508	5,565	6,242	3,369	1,225	26,365

[1] Includes battery cases.

[2] Listed as "polyethylene."

Sources: *Modern Plastics*; R. W. Beck and Associates

The number of firms engaged in manufacturing plastic products is difficult to determine. Many manufacturing firms, such as companies making automobile parts, use plastic as well as other materials in their manufacturing process. Also, plastic fabrication is carried out by many small firms which are difficult to track.

Published information on plastic manufacturing firms is available from the Department of Commerce through its Census of Manufacturers ("CM"). Every five years, the CM provides industry data to the federal government, state and local governments, trade associations, and individual businesses. The most recent CM was published in 1987; the next one is due out in 1992.

The CM publishes its findings by Standard Industrial Classification ("SIC") code. It revised its SIC designation for the plastics industry in 1987. Nine 4-digit SIC codes are now used to identify firms manufacturing plastic products. The digits cover 3081 to 3089, inclusive.

In its 1987 CM, the Department of Commerce reported 10,523 companies manufacturing plastic products. Table 4-2 shows the number of firms for each of the nine SIC categories in the 308 series. The CM provides state-by-state information for all firms with more than 150 employees. Table 4-2 also indicates the number of firms with more than 150 employees for each Northeastern state.

In addition to reporting the number of firms by SIC code, the CM also reports the value of shipments classified as primary or secondary to the industry. This figure can serve as an indication of the level of sales for plastic products. The Value of Shipments for products produced by the plastic manufacturers in the United States exceeded \$61 billion dollars in 1987. The total sale of plastic in 1987 was 54,763 million pounds.

As Figure 1 shows, between 1972 and 1987, the value of shipments from plastic manufacturing firms has increased more than 475 percent, an annual average growth of more than 31 percent.

Because the total number of plastic products and the number of firms producing them is so large, this section of the Report presents detailed information on a number of specific products in three categories. The first includes products currently using a significant percentage of recycled plastic as a raw material and having relatively broad resin specifications. The second category includes products with narrower specifications for resin, some of which use a limited amount of recycled plastic. The third category includes products with very narrow specifications for resin and which do not use recycled plastic as feedstock. The manufacturers of these products do not contemplate using recycled plastic for reasons which are discussed below.

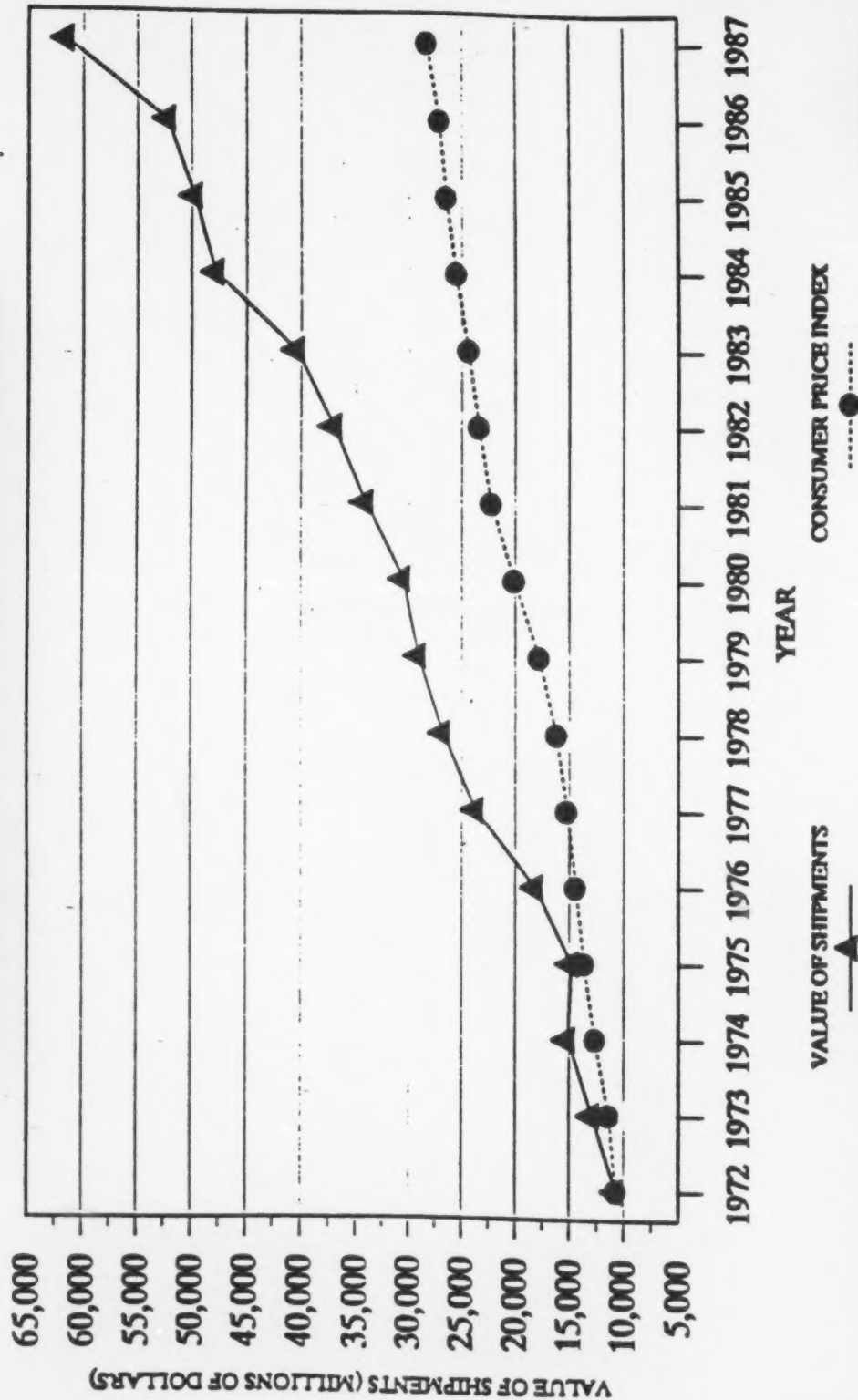
It should be noted here that resin, the raw material from which a plastic product is made, is a critical component of the manufacturing process. Not only does the cost of the resin have a direct bearing on the cost of the product and the profit to the manufacturer, but also the quality of the resin can have a direct bearing on other manufacturing costs. For example, additional labor costs may be incurred if recycled pellet must be cleaned before use. Poor resin quality can reduce equipment productivity,

Table 4-2
Number of U.S. Firms in SIC 308 Series
Reported in 1987

Series	Description	U.S.	Northeast	Percent of Firms in the Northeast
3081	Unsupported Plastic Film and Sheet CT (17), DE (5), MA (36), NJ (57), NY (32), PA (37), RI (4)	474	188	40%
3082	Unsupported Plastic Profile Shapes CT (8), DE (4), ME (2), MA (17), NH (5), NJ (41), NY (45), PA (29)	551	151	27%
3083	Laminated Plastic Plate, Sheet, and Profile Shapes ME (1), MA (9), NH (1), NJ (14), NY (12), PA (12)	214	49	23%
3084	Plastic Pipe NJ (4), NY (7), PA (9), RI (1)	184	21	11%
3085	Plastic Bottles CT (4), DE (2), MA (8), NJ (23), NY (6), PA (11)	155	54	35%
3086	Plastic Foam Products CT (13), DE (3), MA (19), NH (5), NJ (27), NY (40), PA (54)	656	161	25%
3087	Custom Compounding CT (4), DE, (3), MA (21), NJ (26), NY (11), PA (21)	357	86	24%
3088	Plastic Plumbing Fixtures PA (5)	162	5	3%
3089	Plastic Products Not Elsewhere Classified (N.E.C.) CT (165), DE (22), ME (23), MA (347), NH (54), NJ (415), NY (561), PA (402), RI (88), VT (28)	7,770	2,105	27%
TOTAL		10,523	2,820	27%

Source: U.S. Department of Commerce, Bureau of the Census

FIGURE 1
GROWTH IN VALUE OF SHIPMENTS FROM
PLASTIC MANUFACTURING FIRMS, 1972-1987



R.W. BECK
AND ASSOCIATES

(1) SOURCE: DEPARTMENT OF COMMERCE 1987
 CENSUS OF MANUFACTURERS

(2) SOURCE: BUREAU OF LABOR STATISTICS, ALL URBAN CONSUMERS, NORTHEAST

create color problems, lead to losses in barrier properties, and generally result in poor product quality and/or increased manufacturing costs.

Poor product quality may result in dissatisfied customers and a loss of business. It is this relationship between the resin used as a raw material and the final plastic product which will be the focus of the following three sections.

ECONOMICS

Residential post-consumer recycling is only five to ten years old. Therefore there are few precedents for establishing a price relationship between virgin and PCR. Prior to 1987, the majority of recycled post-consumer plastics came from PET soft drink bottles and HDPE base cups collected in the nine bottle deposit states. These limited volumes of PCR resins were sold for use in secondary applications. Prices were fairly low reflecting limited competition.

The majority of plastics used in consumer packaging (LDPE, HDPE, PS, PP, PET, and PVC) are high volume plastics. Virgin pricing reflects a dynamic relationship among production, consumption, raw material costs, and competition. Pricing for PCR is expected to continue to follow virgin resin price trends. Price cycles are inherent in commodity industries. The current downward cycle in virgin prices is reflected in depressed post-consumer values.

Postconsumer resins cannot compete with virgin resins for the following reasons:

- (1) they cannot replace virgin resins because they have undergone a "heat history" during manufacture of the original product which has lowered performance;
- (2) virgin resins are tailored to the processing and property requirements of each application;
- (3) virgin resins are essentially pure and can be pigmented to each product manufacturer's liking; and
- (4) there are added handling costs for the smaller shipments of PCR.

Based on this limited history and R. W. Beck and Associates' analysis, the expected range of pricing would be 60 to 90 percent of virgin (assuming post-consumer in flake form and truck-load quantities, virgin in pellet form and hopper cars). The lower boundary tends to be set by the established industrial scrap market for each resin - for example drain piping uses scrap HDPE from bottles, fiberfill uses scrap PET from bottles. The upper boundary reflects the best case for a post-consumer resin recycled back into the identical application as virgin. This discount at the upper bound would compensate for the reduced performance of PCR. In the United States, natural gas, not oil, provides most of the raw material for plastics. Natural gas liquids such as propane and ethane, comprise approximately 75 percent of the raw materials for plastics. The remaining 25 percent are oil-based products. In Europe, the percentages are reversed. Therefore, changes in oil prices do not affect the price of virgin resins in the United States as much as changes in the price of natural gas.

As new markets develop and improvements in the quality and performance of PCR are implemented, there should be a gradual improvement in their price relationship with virgin. Most post-consumer resin is sold at about 60 percent of the price of equivalent virgin. It would not be inconceivable to reach an average ratio of 75 percent within five years and 80 to 85 percent within ten years.

PRODUCT CATEGORY ONE: PRODUCTS WITH BROAD RESIN SPECIFICATIONS

This category includes products that can be manufactured with resins having broad resin specifications. For example, color can vary slightly over the same product, so strict color matching is not required. In many cases, different types of resin can be mixed without threatening the integrity of the product. Although characteristics such as strength and durability are important in many of these products, the acceptable limits tend to be well within the range of the mixed resin feedstock.

Many of the products in this category have been developed specifically to use commingled plastics from residential recycled programs. Other products use off-spec commercial/industrial scrap, which competes with post-consumer resin ("PCR") in this market.

Commercial/industrial ("C/I") scrap has a number of advantages over PCR. C/I scrap is generally cleaner. It is available in higher volumes from single sources. It also tends to be cheaper because collection and sorting costs are lower. The use of C/I scrap is well-established in certain businesses, such as drainage pipe. HDPE pipe currently uses scrap from milk jug producers as a part of its feedstock. PCR competes with the C/I scrap for this application, with the lowest price winning out.

The discussion of specific products in this category begins with plastic lumber.

Plastic Lumber

In its simplest form, plastic lumber is a compression-molded product which uses flakes of mixed recyclable plastic. The primary resins used are HDPE, PP, LDPE, and PS. Because PET melts at a higher temperature than these other resins, it is used sparingly, if at all. Individual manufacturers develop their own mix of resins, but generally about 65 percent PP and Polyethylene is used, with lesser amounts of resins with higher or lower melting points. The resins with higher melting points remain solid and provide strength; the resins with lower melting points create voids, make the lumber lighter, and produce a smooth finish. Some manufacturers use other material to supplement the recycled plastic. For example, Rivinite of Philadelphia produces a plastic lumber product that uses a mixture of recycled wood fibers and plastic film scrap.

Plastic lumber can be made in standard dimensions to be used for landscaping, decks, picnic tables, and other outdoor applications. It is impervious to rot and weather and resists attack by chemicals and bacteria. It does not need painting or finishing and can be dyed natural wood colors. It can be sawed, nailed, screwed, planed, or routed, just like natural wood. Furthermore, it does not contain the toxic preservatives used in pressure-treated lumber. However, if the mix of plastics and additives varies significantly from batch to batch, the characteristics of the lumber can also vary. The Pennsylvania Parks Department has found that in some applications, plastic lumber has cracked and warped, making it unsuitable for construction.

Plastic lumber appears to be an ideal product application for recycled plastic because it can be made from 100 percent recycled content. However, the manufacturers of plastic lumber want a controlled feedstock

to ensure consistency in the final product. This means that, even though the supply of plastic may be a mix of resins, the mix must be consistent over time. Variances in consistency will be a barrier to utilization.

An important disadvantage of plastic lumber is its relatively high cost compared to natural wood. In some cases, a plastic lumber 2 x 4 can cost twice as much as its natural wood counterpart. There is also a public perception that "plastic" wood, especially when it is made from trash, is an inferior product compared to natural wood. Some people object to its appearance. Recent efforts to educate the public to buy recycled products has helped to overcome these perceptions.

Although plastic lumber will not replace wood in all applications, it appears to be particularly well-suited to certain products, such as picnic tables, fence posts, and landscape timbers. Although more than a dozen manufacturing firms have entered the market for plastic lumber in the past few years, there are indications that the market is reaching saturation, primarily due to quality and cost constraints. In March 1992, Plastic Recyclers, a mixed lumber producer in Bay Shore, New York went out of business citing a "soft market for plastic lumber products."

Until the market for plastic lumber expands, this product will not have a significant impact on the demand for mixed plastic scrap. Market expansion will depend on making plastic lumber more cost-competitive through more efficient manufacturing technologies; changing the public perception that plastic lumber is an inferior product; and more aggressive government procurement policies. For a discussion of the role of state and local governments in buying recycled plastic products, see the "Government and Industry Roundtables on Buying Recycled Plastic Products," (The Council For Solid Waste Solutions, August, 1990).

Marine Applications

A special application of plastic lumber is marine applications such as docks, floats, and piers. Because plastic lumber does not rot, it appears to be an ideal material for these types of building projects. The mix for these applications may have to be tailored as strength becomes more critical.

A few demonstration piers are now being constructed on the East Coast, and several manufacturers believe that these demonstration projects will

convince consumers and government purchasers of the value of this material. The Solid Waste Association of North America ("SWANA") is evaluating marine applications of plastic lumber. The results should be available in early 1992.

Recycling Containers

The household recycling container is a bin ranging from 5 to 20 gallons designed to hold recyclable materials separated from the trash by residents. In some cases, these containers are purchased by the household and, in other cases, the community purchases the containers as a way of promoting the recycling program.

In an effort to use recycled plastic, many of the municipalities that purchase household recycling containers for their residents are requiring recycled content. Containers must meet criteria which may include color, capacity, shape, durability, and recycled content. These containers are often placed at the curb on collection day and must stand up to severe weather conditions.

Home composting containers can also be manufactured from PCR. For a discussion of the testing and procurement process that the City of Seattle, Washington conducted in purchasing backyard composting bins, see Resource Recycling, August, 1991.

Household recycling containers are injection-molded HDPE, with some manufacturers adding LDPE, rubber, or other materials for additional strength or other qualities. The advertised recycled content in these containers ranges from 0 to 100 percent post-consumer HDPE. Very high percentages of PCR will require a very clean supply of scrap. Just before molding, injection-molded plastic is fed through a screen to remove contaminants. If the level of contamination is high, the screens must be changed frequently, slowing the manufacturing process, reducing production levels, and increasing the cost of the containers. At the present time, a range of 25 to 50 percent appears reasonable, if a clean and consistent supply of PCR is available.

Many communities also want containers with a specific color, such as yellow or orange, which requires that the scrap used be translucent HDPE from milk and water jugs. If the darker material from detergent or motor oil bottles is used, the containers will have to be gray or black. These communities must understand that if they choose to recycle these

products, they should be able to purchase recycled products that are limited to certain color categories.

As municipal recycling programs have grown, the market for these types of container has expanded, with more than fifty firms currently selling containers. However, future growth of this market is limited. Of the approximately 93 million households in the United States, about 72 million households are located in Metropolitan Statistical Areas which would probably be served by a curbside recycling programs. Something less than 72 million (perhaps 50 to 60 million) households would be a reasonable estimate for the number of households which would use one or more recycling bins, since some communities will chose blue bags or other containers. Many communities have already purchased containers. Most communities use an annual replacement figure of 5 percent to account for theft, loss, or residents moving and taking their container with them.

The use of a container with recycled content to collect recyclable materials invites a simple calculation of recovery and procurement, such as the following:

Given a community with:

- 100,000 residents and 37,500 households (2.67 persons per household)
- the national per capita generation rate of 2.9 pounds of HDPE milk jugs
- a recycling program collecting 75 percent of the available milk jugs
- a procurement program which buys one HDPE recycling container for each household, plus 5 percent per year thereafter. Each container weighs 2.5 pounds and has 50 percent post-consumer recycled content.

The community will collect 217,500 pounds of HDPE during the year. The community will also purchase, in the form of recycling containers, 46,875 pounds of post-consumer HDPE, or 22 percent of what is collected, in the first year. Of course if the community purchases two bins per household, or obtains containers with a higher post-consumer content, the percentage of collected HDPE will be higher. Unfortunately, in later years, as only

the replacement bins are purchased, a very small percentage of the collected HDPE will be repurchased in the form of containers.

In order to stimulate demand for PCR, communities or states may wish to provide some short-term price preference for bins, or other products with recycled content. However, procurement policies should be performance based. That is, all products which are purchased must meet the same performance standards (color, strength, durability, etc.). If products with recycled content are held to lower standards, it will perpetuate the mistaken idea that recycled products are lower quality. It will also allow manufacturers with shoddy standards into the marketplace.

Because both individual residents and municipalities have a better understanding of how important it is to stimulate the markets for recycled materials, purchasing household containers with recycled content should be an obvious step.

PRODUCT CATEGORY TWO: PRODUCTS WITH NARROW RESIN SPECIFICATIONS

This category of product has traditionally been manufactured from virgin resins because of strict performance requirements and competitive material cost. The product designer establishes specifications for the product in terms of automated, physical, thermal, and application-specific properties. Processability standards (a balance of high production rate and high quality) must also be met. The material choice is based on an optimum balance of these criteria at the lowest cost. Technological improvements have resulted in resins tailored to specific applications and with the ability to meet applicable regulations (such as the Food and Drug Administration and the Department of Transportation). Therefore, virgin plastics have often become the material of choice in many narrow specification products. As post-consumer plastics recovery has grown, partial displacement of the virgin material has occurred where performance compromise is minimal.

A considerable variety of such narrow specification products ultimately becomes residential PCR. These include HDPE milk jugs, PET soft drink bottles, HDPE detergent and motor oil bottles plus numerous other food, drug, toiletry, cleanser, and household containers.

Other products having narrow resin specifications include smaller rigid products such as: polystyrene food trays, hinged and hot beverage

containers and cutlery; HDPE trash receptacles, dairy and ice cream tubs; LDPE lids for coffee, margarine, nuts, etc.; and PVC and PET blister packs. Packaging film products include LDPE for baked goods, frozen products, garment bags, and handle merchandise bags; polypropylene for cigarette wrap, snack foods, and cookies; HDPE for grocery sacks, merchandise bags, and food box liners; and PVC for fresh meat and produce wrap.

Given this wide variety of products with narrow specifications, the discussion will focus on the following representative examples:

- PET Soft drink Bottles
- Non-food Bottles, such as detergent & motor oil
- Films – grocery sacks, apparel bags, & trash bags
- Construction Materials – shingles, insulation board, film
- Highway Construction – Cones, barricades.

Recycled Content Driving Forces

The growth in PET soft drink bottles since their introduction in 1978 has been phenomenal. One-third of all soft drink is packaged in PET. However, most of the growth has been in the large 2-liter size where the lightweight, shatterproof, less expensive PET bottle is far superior to the old 32 oz. and 64 oz. glass bottles. Competitive pressure from glass and aluminum in smaller sizes is extreme and will moderate overall penetration of PET in soft drink bottles. (See Table C-1 in Appendix C, Section 1.) We would expect future growth at levels of about 5 percent per year.

The shift to recycled content and post-consumer recycling of products having narrow specifications has been driven by several factors, including consumer awareness, competition, economics, and legislation.

The economic forces that have driven the recycling of postconsumer plastics have been rising tipping fees at waste disposal sites and revenues from value-added markets. Tipping fee cost avoidance, through recycling, has become the common waste management strategy for municipalities. The relatively stable markets for PET and HDPE have been an added incentive to recycle.

PET soft drink bottle recycling, which began in 1979, was initially dictated by competitive pressures — glass bottles and aluminum cans had already established recycling programs. Bottle deposit laws aided in creating a supply of collected PET. More recently, growing consumer awareness and environmental concerns about "closing the loop" led to Coke and Pepsi to introduce 25 percent recycled content bottles this year in test markets.

Detergent and motor oil bottles represent sufficient volumes of recyclable plastics to warrant their recovery and reuse. Reacting to consumer pressures and pending legislation, several consumer product companies initiated programs to provide recycled content containers. Competitive marketing also has driven this transition as the "shelf appeal" of bottles with recycled content is extremely desirable.

Plastic grocery bag recycling programs have been initiated by some supermarket chains in response to consumer awareness and environmental concerns about these films. Many of these bags, which are mostly HDPE, currently are recycled back into grocery sacks or trash bags where color and direct food contact are not critical concerns.

PET Soft drink Bottles

In 1990, 30 percent of PET soft drink bottles in the United State (225 million pounds) were recycled — all into secondary uses. PET soft drink bottles have been recycled into textile products such as carpet fiber, fiberfill, and geotextile applications since 1979. The largest single market for virgin PET is fibers (in excess of three billion pounds in 1990). Fiberfill applications require a much lower molecular weight version of PET than soft drink bottles. Therefore, recycled PET from soft drink bottles is a very desirable material for fiberfill.

Using recycled PET in soft drink bottles previously was not considered due to stringent Food and Drug Administration regulations on direct food contact, but PET is now being recycled back into soft drink bottles. PET bottles with 25 percent recycled content are being test marketed. Direct food contact usage is possible only because of new technology in which the PET molecule is broken into its basic components, purified, and remanufactured. The companies making high purity recycled resin produced by this process have received a "letter of no objection" from the Food and Drug Administration for direct food contact use in new PET

bottles. The test marketing of recycled content in Coke and Pepsi bottles is in progress today in a few communities.

Closed loop recycling of PET soft drink bottles could absorb a major volume of recycled material. At the current 25 percent level, PET recycling could double its existing markets. However, there are several barriers to overcome. Most critically, the process that makes high purity recycled PET is not economically viable. Several companies (DuPont, Eastman Chemicals, and Hoechst-Celanese) are working to improve this technology and hope to demonstrate its commercial viability by early 1992. If these efforts fail, the economics of meeting Food and Drug Administration requirements will impede closed loop recycling of soft drink bottles.

There is a critical need for additional supply of PET to meet existing applications and provide for new end-uses such as the closed loop bottles. The expansion of recycled content markets combined with new technological developments will continue to drive the need for more supply.

The supply of high quality recycled PET is essential for growth in recycling of soft drink bottles. Quality requirements become more critical as the end-use changes from fibers to bottles to thermoformed containers (egg cartons and fresh fruit containers). Automatic sorting and cleaning technologies are constantly being improved. In most operations, some degree of hand sorting is still practiced using the SPI identification code and visual inspection.

Barriers to Unlimited Recycled Content

In addition to meeting stringent Food and Drug Administration standards for reuse in food containers, PCR must also satisfy all the functional requirements of the new container. The most cost-effective method for producing PET soft drink bottles is injection stretch blow molding. However, this inherently stressful process shortens some of the long molecules lowering certain physical and automated properties. As a result of these changes, plastics recovered from PCR are slightly degraded. The amount of degradation depends on a variety of factors including: resin type, molecular weight, processing conditions, and moisture content. For example, molecular weight of recovered PET soft drink bottles is 10 percent lower than that of the original PET. This irreversible change (1) reduces key automated properties such as stiffness and impact strength

related to bottle lightweighting and performance; (2) reduces barrier properties essential for product protection and shelf life; (3) causes discoloration; and (4) can cause melt fracture (i.e., the melted plastic breaks during molding).

One result of irreversible change is that PCR cannot simply be a replacement for a virgin resin. New approaches and new technologies are being developed to overcome this barrier and provide PCR tailored to specific applications. Manufacturers are developing tailored resins by reformulation and by adapting virgin resin techniques to improve molecular weight and other properties. Reformulation may be done in a number of ways: (1) compounding PCR with reinforcements and impact modifiers to improve automated properties; (2) chemical bonding of incompatible polymers resulting in the benefits of a blend or alloy; (3) additive incorporation to improve processing, minimize heat degradation, or control crystallinity; and (4) adaptation of commercial technologies (such as solid stating of PET and methanolysis) to upgrade properties of PCR for value-added applications. Creative upgrading of recovered plastic resins will continue to grow as reclaimers target their products for value-added markets.

As indicated, the potential expansion of soft drink bottle recycling by closing the loop is dependent upon technology, continuing Food and Drug Administration cooperation, and increased supply of quality recycled PET. The strong market position of the PET bottle is expected to continue. The technical issues are beyond the control of state and local governments. However, expansion of existing collection programs for all recyclables, including PET, will positively impact its recyclability and reduce the amount bound for landfills. To aid on the quality problem, all states should mandate the use of a national coding system (since bottles and rigid containers cross state lines) on the bottom of plastic bottles and rigid containers. Such a coding system would identify the resin, fabrication technology, and melt flow index to provide all the information which would be needed to separate recycling-compatible streams.

Non-Food Bottles

This category of products encompasses a wide variety of non-food and non-drug bottles which do not have to comply with Food and Drug Administration regulations. They are predominately made from different types of HDPE, with smaller quantities from PVC, polypropylene, and

PET. As a group, this category of virgin bottles represents about one-third (about 1.2 billion pounds per year) of all plastic bottles. Detergent and motor oil bottles will be discussed as representatives of these containers.

Recycled content detergent and oil bottles, both made from HDPE, were introduced over the past two years. The recycled percentages for post-consumer are 25 percent for detergents and 15 percent for motor oil. Total recycled content use of HDPE in non-food bottles was 75 million pounds in 1990.

These bottles represent an excellent, high volume market for recycled HDPE. The majority of HDPE food containers (milk, water, non-carbonated beverages, and juices) recovered from curbside programs are recycled into detergent and oil bottles. Because of chemical differences between PET and HDPE, the technology previously discussed for PET is not applicable to HDPE. Therefore, the Food and Drug Administration will not allow the use of recycled-content HDPE in food containers. Detergent bottles collected from curbside programs are also recycled into new detergent bottles (as an inner layer) or as a blended resin for oil bottles.

The blow molders have had to adapt their equipment to process PCR. The recycled resin has slightly different melt properties than virgin due to its additional heat history (the molding process for making the original bottle reduces melt strength of the plastic). In addition, the requirement to resist failure from attack of harsh liquids (environmental stress crack resistance - "ESCR") varies from low requirements for milk jugs to medium requirements for motor oil to high requirements for detergents. It is this property that limits recycled content in motor oil bottles to 15 percent. For detergent bottles, which require high ESCR, a three-layer structure is required to satisfy product performance. The inside virgin layer provides stress crack resistance, the outer virgin layer provides color control, and recycled resin (25 percent trim scrap and 25 percent post-consumer) is in the middle. Expectations are that the percentage of post-consumer in the three layer detergent bottle can eventually increase to 40 percent while postconsumer content in the single layer oil bottles will be increased to 25 percent. Current material, equipment and design technology cannot produce bottles meeting all specifications above these recycled content levels.

Just as with soft drink bottles, a quality supply of recycled resin is critical for use in recycled content non-food bottles. In addition, the separation

of translucent bottles from pigmented bottles is also helpful. The translucent bottles can be pigmented to match color in the recycled bottle (the Tide orange or Pennzoil yellow). The mixed colors from detergent bottles can only be pigmented black or buried in the middle layer.

Again, state and local governments can stimulate recycling by including all blow molded HDPE bottles, in collection programs, if their processing capacity is adequate and markets are available. Mandating the use of an identification code would aid in manual sorting of bottles, when necessary. Education on the technical limits of recycled content volume in non-food bottles will help change perceptions that all bottles should contain 100 percent recycled material. The technical barriers are real, although research is being completed to utilize higher recycled content without performance compromise.

Plastic Films

Plastic films are for food protection, retail bags, apparel wrap, trash bags and many other applications. They are predominately made from LDPE, with lesser amounts of PP, HDPE and PVC. This category represents over 5 billion pounds of resin sold in 1990. About 34 million pounds of film bags were recycled last year. The post-consumer collection of grocery or T-shirt sacks is primarily done through drop-off bins at the point of sale.

Post-consumer recycling of plastic films began in 1989 when several national supermarket chains encouraged consumers to return plastic grocery sacks for recycling. These initiatives were motivated by environmental concerns and pending legislation against non-recyclable materials. The availability of improved technology for handling post-consumer wastes was also a motivating factor. As research on degradability in landfills dispelled the belief that degradable films would help solve the landfill crisis, the critical need to recycle films became apparent.

Recycled content grocery sacks are being produced by several film companies including Key Packaging Industries in Salem, NH. Also in the Northeast, Union Carbide is starting a major new processing facility at Piscataway, NJ for cleaning, separating (by color and film type), and upgrading post-consumer films. Reclaimed resins are then mixed with virgin resins and additives to upgrade properties. This step is required because recycled resins suffer some loss of properties each time they are

re-extruded. New grocery sacks contain up to 50 percent recycled HDPE with post-consumer content at about 20 percent. As the supply, quality (clean, dry, and free of paper), and cleaning technologies improve, post-consumer content could increase to the 50 percent level.

Beyond closed-loop markets, the HDPE from grocery sacks can also be blended into trash bags and institutional can-liner applications where color and specifications are less critical. These films are predominately made with LDPE and could incorporate about 15 to 20 percent of this recycled HDPE. The technical limit on compatibility arises from differences in molecular structure, processing characteristics, and other properties of HDPE and LDPE. However, the consumption of virgin LDPE in trash and institutional bags totaled 1.6 billion pounds in 1990 – a substantial potential market for recycled HDPE grocery sacks.

Successful grocery sack recycling programs have been based on linking the consumer, retailer, and processor. Consumers must be educated to return bags in clean condition. The retailers must provide a convenient drop-off container with clear instructions for the types of bag being recycled. Processors must specify the type(s) of plastic film their sorting and reclaiming systems can handle. These programs are relatively new and most stores do not keep accurate records of the return rates. Vanguard Plastic, a major supplier of recycled content grocery sacks, estimates that grocery bag return rates for the stores it deals with average about 15 percent.

One perceived barrier to recycling of plastic films is the misconception that biodegradable bags, whether they be paper or modified plastic, disappear once they are landfilled. Landfill explorations have shown that organic materials such as paper and food wastes do not degrade in most landfills. It is important to communicate that biodegradability is not a solution to the landfill crisis so that consumers do not become complacent about the need for recycling. Not only is "biodegradable" a misnomer for plastic film which is likely to be landfilled, but the use of corn starch, as a means of creating a "nominally" biodegradable plastic bag, tends to weaken the bag. For a full discussion of this issue, see the Final Report of the Degradable Plastic Task Force (March, 1991), available from the Illinois Department of Energy and Natural Resources.

Communities that use plastic bags for curbside or drop-off collection of recyclables could stimulate the market by purchasing recycled content bags from film producers in the Northeast. Municipalities and state

governments can also stimulate film markets by establishing performance-based procurement guidelines for a number of products (including trash bags, can liners, and bubble packs) made with recycled content.

Construction Materials

Although the use of recycled content resins in construction is somewhat limited at this time, this market represents the second largest end-user of virgin plastic materials. Several major applications where residential scrap could be used include PVC in flooring (417 million pound market) or as a vapor barrier film (58 million pound market), PET in insulation (480 million pound market), polystyrene in insulation (232 million pound market), and LDPE as a vapor barrier film (182 million pound market).

Recycled content materials in the building industry include waterproofing board from polystyrene, insulation board from both PET and polystyrene, and vapor barrier film from LDPE. Also, computer housing from obsolete PC's are being recycled into roofing shingles. The more critical structural components in buildings are made with higher strength engineered resins and alloys, not commonly used in consumer packaging.

The Garbage Project at the University of Arizona has calculated that construction and demolition debris accounts for 15 percent of landfill space. With this increased attention on construction and building wastes, the industry is becoming more proactive toward environmental issues. The use of recycled content materials would reduce the amount of landfill-bound virgin plastics and provide another secondary market for resins collected at the curbside.

Building code restrictions will not impact on these applications discussed above, but will limit penetration of recycled materials in structural, high pressure or flame retardant construction applications.

State financed construction projects can stimulate this market by specifying recycled content in procurement, and reviewing existing specifications that require virgin materials in products.

Highway Construction Supplies

Durability, maintenance-free characteristics, and low cost make plastics very desirable for highway safety indicators and barricades used during road construction projects. These materials are impervious to the extremes

of climate and weather, never require painting, and survive continuous abuse.

Safety barricades made from recycled content HDPE are being produced and used in Illinois through a plastics recycling partnership between DuPont and the Illinois Department of Transportation. Traffic cones are being manufactured by Utility Plastics, a subsidiary of Brooklyn Union Gas from recycled PVC wire and cable coatings. These new developments illustrate the key role that public and private partnerships can play in establishing programs with positive environmental impacts.

PRODUCT CATEGORY THREE: PRODUCTS WITH VERY NARROW RESIN SPECIFICATIONS

The final category includes products that use no recycled plastic and, because of the very strict resin specifications, are unlikely to do so. The manufacturers of these products have not used recycled plastic because the technical or perceived barriers are too great. By examining two classes of product in more detail, the barriers faced by these firms, and the unlikelihood that these barriers can be overcome will become clearer.

The primary barrier to the use of recycled plastic in products with very narrow resin specification is manufacturers' strict performance requirements for purity, color, strength, or consistency. Manufacturers see these requirements as intimately tied to the successful performance of these products, as well as to the success of these products in the marketplace. As a result, firms are very reluctant to relax these standards. Manufacturers fear that if the standards are relaxed, the product will fail to perform and lose its competitive position in the market. Two categories of product -- disposable medical products and automobile parts -- are examples.

Medical Products - Blood Bags, Tubing, and Syringes

Disposable plastic medical products have become a fixture in modern hospitals and their use in hospitals is increasing at the rate of 5 to 7 percent per year. Disposables guarantee a sterile product for every use. They eliminate the need for expensive labor and equipment to sterilize instruments, and they are also more convenient for hospital staff who simply throw the product away after use. These products also enjoyed a

clear cost advantage over permanent instruments, as long as waste management costs were low. However, increasing waste disposal costs have begun to change this.

Given the small amounts of PVC and PP in the residential waste stream, and the risk of contamination, however small, of using PCR, it is unlikely that hospitals or manufacturers will consider using recycled plastic for these products.

Blood bags and tubing are manufactured from extruded PVC. It is estimated that in 1990, approximately 76 million pounds of PVC was used for blood and solution bags and an additional 76 million pounds for medical tubing. Injection-molded PP syringes consumed about 135 million pounds of the resin in 1990.

The risk of contamination is a primary concern of hospitals. In August, 1987, the U.S. Centers for Disease Control ("CDC") issued guidelines for the handling of waste in medical facilities. The guideline, generally referred to as "universal precautions" recommends that all waste categorized as patient waste be considered infectious. This recommendation has been endorsed by the U.S. Department of Labor, Health and Human Services, and the Occupational Safety and Health Administration as a protective step to ensure the safety of healthcare workers. The use of disposables is an essential step in implementing the universal precautions. Therefore, hospitals are using disposables to avoid contamination.

There are no federal regulations which specifically address resin content of plastic medical products. The manufacturers of plastic disposable products have two concerns which keep them from using recycled resin. First, the performance standards for many of these products is very high. They must function without fail under exacting conditions and be impervious to viral and bacterial invasion. They also require a variety of strength properties which result in very tight resin specifications. In addition, these products must also stand up to the rigors of sterilization. At the urging of the Food and Drug Administration, manufacturers are increasingly using gamma ray radiation to sterilize medical products. Unless resins are specifically formulated to withstand radiation, the product will yellow and become brittle. This further narrows the resin specifications for these products.

The second concern of manufacturers is consistency of feedstock material. Manufacturers regard it as critical that products consistently maintain high

performance standards. The risk that the quality of PCR would vary from batch to batch makes it unacceptable as a potential feedstock material to these firms. For example, Becton Dickinson, a major manufacturer of disposable syringes, expects that the clarity of all the syringes they manufacture will be identical. Any risk that the clarity would be compromised by variations in feedstock is unacceptable.

Automotive Products

The typical automobile today uses about 230 pounds of plastic. About 65 percent of these plastics are thermoplastics such as PP, HDPE, and PVC. The remaining 35 percent are thermosets, such as fiberglass and epoxy. The average amount of plastic used in an American automobile has increased from roughly 168 pounds in 1977 to 230 pounds in 1990. The switch to plastic has taken place primarily to reduce the weight of the automobile, thereby increasing gas mileage. The growth in the use of plastic automobile parts has collided with the growth of recycling and forced manufacturers to address the recyclability of their product.

Automobile manufacturers are addressing the recycling of automobile parts through the Society of Automotive Engineers ("SAE"). The SAE is revising its coding system for automobile parts to aid in recycling. The revised code will be similar to, but not identical to the SPI code for plastic containers. The SAE's original code, which was developed in 1980, encompassed over 200 different symbols to identify polymers, fillers, and other additives. It was designed to assist auto dismantlers and dealers in identifying parts. The revised code is directed more toward recycling and is partially in response to Michigan Public Act 414 which requires that certain automobile parts be labeled for recycling. Act 414 affects only certain parts.

Plastic automobile parts include two types of products: those with narrow resin specifications, similar to the specifications in Product Category Two, above, and those with very narrow resin specifications. Products with narrow specifications include fluid reservoirs for anti-freeze, windshield washer fluid, coolants, plastic gas tanks, and battery cases. Reservoirs are made with HDPE; battery cases and gas tanks use PP. The barriers to utilizing recycled plastic in manufacturing these products are similar to those of products such as detergent bottles, which are discussed in Category Two, above.

Products with very narrow high resin specifications and include bumper fascia, cladding (the protective strip along the automobile's exterior), and wheel covers. Most expensive automobiles have color-matched bumper fascia which are made with acrylonitrile-butadiene-styrene ("ABS"). The black plastic bumpers on less expensive cars are PP. Cladding is a combination of polycarbonate ("PC") and PET. Wheel covers are a combination of PET and PC. Because ABS and PP are found in limited amounts in the residential waste stream, these parts do not hold great promise as a potential application for PCR.

In addition, the automobile industry uses very strict standards for its parts and feedstock, particularly in parts which require color-matching. Only one supplier, Eastman Chemical sells resins directly to auto makers. All other resin suppliers must send their resins to a compounder who pigments the resin before it is fabricated into a part. This second step ensures that colors are perfectly matched. Automobile companies also subject their parts and materials to severe performance tests against extremes of temperature and impact before accepting them. These demanding tests discourage manufacturers from risking rejection because of potential contaminants of PCR.

CONCLUSIONS

1. The following are barriers to the use of recycled plastic in products with broad resin specifications.
 - There are a limited number of products with broad resin specifications.
 - Durable products, such as plastic lumber and recycling containers, will not provide a closed-loop end-use for plastic recovered from non-durables such as packaging.
 - Markets for many products with broad resin specifications, such as plastic lumber and flower pots, are limited.
2. Opportunities for recycled products with narrow resin specifications have been growing as improvements in the supply of PCR, technologies, and markets occur.

3. The following are barriers to the use of recycled plastic in products with narrow resin specifications:
 - Regulations regarding direct food containers,
 - Technical limits to recycled content,
 - Supply and quality of collected scrap,
 - Consumer perceptions of plastic recyclability,
 - Manufacturers concern about the use of recycled resins.
4. Manufacturers of products with very narrow resin specifications are not likely to incorporate PCR into their products for the following reasons:
 - Many products use resins which are not found in large amounts in the residential waste stream, such as PP and PVC.
 - PCR does not meet the resin specifications standards of these manufacturers and current technology is not capable of consistently bringing the quality of the PCR to these standards.

RECOMMENDATIONS

1. Because post-consumer resin ("PCR") will compete with both virgin resin and commercial/industrial scrap, the importance of developing a clean, well-sorted supply of PCR is critical to the success of recycling.
 - NERC should encourage manufacturers to "design for recyclability" by urging the use of identical, or at least recycling-compatible, resins in product types.
2. NERC could encourage the purchase of recycled plastic products by individual consumers and government entities.

Section 4

3. NERC should encourage performance-based standards for government procurement policies. The public will not be served by encouraging lower standards for recycled products.

For the long-term, recycled products should compete equally with products made with virgin resin. A graduated price preference for some products for two or three years may be advisable, but this should be phased out as soon as possible.

4. Minimum content legislation can be an effective tool in promoting the recycling of plastic.

- NERC can coordinate legislative initiatives within its membership, and beyond, so that the manufacturers of plastic products are not faced with multiple state standards for recycled content of products.
- A recycled content of 10 percent for plastic products with narrow resin specifications is reasonable and technically feasible, assuming a clear supply of PCR is available. An exception for products requiring Food and Drug Administration approval would have to be allowed. Percentages in excess of 10 percent are not technically feasible for many products at the present time.
- NERC should be aware that the timing and structure of minimum content legislation is very important. Commodity prices, such as those for virgin resin, tend to be cyclical. The current low price of virgin resin is forcing the price of recycled resin down. Legislation providing price supports or other incentives may not be necessary when the price for virgin resin cycles upward.

5. Along with coordinating minimum content legislation, NERC could also promote and coordinate labeling standards, so that manufacturers and consumers would have a clear understanding of the recycled content of plastic packages and products.

6. Certain technical problems in recycling plastic, such as the degradation of plastic as it is recycled, must be solved by the industry. NERC may

wish to encourage research and development by industry in areas such as:

- Sorting technologies
 - Application of technologies for upgrading or improving recycled resins to meet higher performance standards
 - Development of new products specifically designed for recycled plastics
 - Development of improved manufacturing processes for fabricating recycled resins into finished products
 - Commercialization of depolymerization technologies to increase the quality of PCR.
7. Governments should provide incentives to manufacturers encouraging them to test market new products using high percentages of PCR.

Section 5

CONCLUSIONS AND RECOMMENDATIONS

Section 1

CONCLUSIONS

1. The seven resins which are the focus of this Report accounted for 72 percent of total U.S. sales of plastics in 1990.
2. These seven resins also accounted for about 99 percent of the non-durable consumer products manufactured; about 45 percent of the durable consumer products; and 64 percent of the commercial/industrial products.
3. The three individual resins most commonly found in non-durable consumer products are HDPE, LDPE, and PS.
4. By far, the plastic application accounting for the largest fraction of the plastic waste stream is film. Other easily identifiable plastic products which are plentiful in the waste stream are PET soft drink bottles, HDPE bottles for household chemicals, and HDPE milk jugs.

<u>Product</u>	<u>1990 Sales (millions of lbs)</u>	<u>Percent of 1990 Sales</u>
Plastic Film	4,908	7.98
PET soft drink bottles	754	1.23
HDPE household chemical bottles	926	1.51
HDPE milk/water jugs	736	1.20

5. Because HDPE, LDPE and LLDPE film are similar in appearance, residents and businesses will have difficulty distinguishing among them.

RECOMMENDATIONS

1. Based on the amounts of HDPE used for milk and water jugs and the amounts of PET used for soft drink bottles, residential recycling programs should continue to collect these products.
2. Film recycling holds promise as a means of substantially reducing the commercial and institutional plastic waste stream.
3. Because PP and PVC are relatively small fractions of the residential waste stream, these two resins should not be targeted for collection unless an efficient and cost-effective sorting technology can be developed.

Opportunities may exist for recovering PP and PVC in durable products or from commercial/industrial sources.

4. Although the amount of PS sold to consumers and disposed of by residents suggests that this resin could be targeted for recycling, difficulties with collection and contamination make it expensive to recover from the residential waste stream. A more cost-effective approach is to identify specific commercial and institutional locations, such as schools, fast-food restaurants, and institutions, such as schools, which generate large amounts of relatively clean PS that could be targeted for recycling programs. This approach is already being used in many schools and other locations in the Northeast.

Section 2

CONCLUSIONS

In terms of recovery, postconsumer resins/products can be divided into three groups.

- (1) Resins/products which are being successfully recovered at the present time, include PET soft drink bottles, HDPE milk and water jugs, HDPE pigmented consumer bottles which have not contained chemicals, PP battery casings, and HDPE soft-drink base cups.

CONCLUSIONS AND RECOMMENDATIONS

- (2) Resins/products which have good potential to be recovered in the future, but must overcome relatively minor barriers to recovery, including custom PET bottles (for Spic and Span and Gatorade), PET x-ray film, HDPE household chemical bottles, HDPE and LDPE/LLDPE film bags.
- (3) Those resins/products which currently face significant barriers to recovery, including PS packaging from residential generators, PVC bottles, and PP bottles. These barriers may be overcome by public/handler education and commercialization of automated sorting technology.

There are a number of resins/products which might be targeted for recovery from institutional/commercial/industrial generators, including PET x-ray film, HDPE stretch and shrink wrap, agricultural film, HDPE crates, drums, pallets, and pails, PVC pipe and conduit, PVC siding, and PS food service products.

RECOMMENDATIONS

The following recommendations should lead to increased recovery of a broader range of plastics over a longer time period. Additionally, if pursued, these recommendations should improve existing recovery programs.

- Mixed residential film recycling has potential for recovery but should not be pushed forward too rapidly. Rather, observation of the progress in facilities such as Rhino-X, Petoskey Plastics, Inc., Southeastern Recycling, and North American Plastics should precede the implementation of large-scale programs. Alternatively, film should be targeted for commercial and industrial recovery.
- An education program for reclaimers of silver from X-ray film is recommended, to raise awareness about the recyclability of PET film. Perhaps a match program of PET reclaimers with silver reclaimers could also be undertaken, to make sure the PET material has an outlet prior to the silver reclaimer making changes in solutions.

- Because of stable markets, valuable end products, and a well-developed infrastructure, PET bottles should be targeted for recovery, although focus should be placed on designing PET non-soft drink bottles for recycling and public education stressing bottle rinsing and drainage.
- Processors of PET and HDPE could cooperate with the PVC industry to sort and make available for shipment PVC bottles from mixed streams.
- Product definition (i.e., the designation of containers by product type, brand name, or shape, such as soft drink or narrow neck bottles) should be used to enhance public education. Number codes should only be used if markets are secured for the wide range of materials generated by using the number codes such as custom PET bottles or injection grade HDPE.
- Proper drainage of bottles should also be emphasized in public education, particularly with regard to bottles containing hazardous waste.
- A modest training program to help full-time sorters in plastic sorting facilities identify containers such as PET look-alikes (e.g., PVC Wesson Oil bottles) could improve recovery of the plastic bottle stream.
- EPA should take the lead in re-examining the recommendation for proper disposal of home use medical waste in light of contamination of recyclables, especially those generated in mixed waste processing facilities.
- To balance virgin resin production and price cycles, industry could consider the development of recycling capacity on the front end of petrochemical plant expansions.
- Reduction of cross-contamination through recyclability campaigns, technical assistance, or legislation should be pursued.
- The public procurement of recycled plastic products would greatly improve the absorption of postconsumer products. Mandated public procurement of recycled plastic products at the local, state, and federal levels of government should be strongly supported.

Section 3 CONCLUSIONS

- On-board plastic compactors are efficient, economical, and compatible with most collection and processing systems.
- Drop-off programs for all plastics are useful in rural areas and in supermarkets for film plastic collection.
- Bottle deposit legislation may help spur the collection of certain plastic items in a clean, homogeneous stream. Such legislation may also undermine the collection of other plastic products at the expense of other plastic products or collection methods. (PET soft drink bottles collected in such programs leave little revenue-producing plastics to help support curbside programs.) At the same time, deposit legislation has led to the recovery of large amounts of PET soft drink bottles and has been responsible for creating the bottle recycling infrastructure in those states with deposit legislation.
- Mixed waste processing facilities may or may not, in the future, be responsible for the collection of much greater levels of plastics for recycling. However, high levels of contamination of certain items, such as plastic film, have characterized these facilities.

Current centralized sorting techniques are almost exclusively performed with the use of manual labor. It is unlikely that extensive automated sorting will become commercially available for at least the next 12-18 months.

Until such time, improving the cost effectiveness of hand sorting will rely upon the development of clear educational literature for collection program participants emphasizing the product types or physical characteristics of the bottles to reduce contamination levels before reaching the plastic handler's facility. Moreover, eliminating certain unnecessary handling procedures such as baling and debaling and improved sorting and the addition of the grinding activity at the MRF/plastic handling facility (subject to reclaimer acceptance of ground material) could not only improve the net profit margin of these facilities, but could also reduce the cost associated with the transportation of waste materials invariably found in mixed bales.

RECOMMENDATIONS

- Curbside collection of residential postconsumer plastics should be chosen by any municipality capable of supporting such a program.
- Commingled collection may or may not be more economical than separated collection depending on the presence of a MRF, applicable MRF charges and the existence of other recycling infrastructure.
- Drop-off (as well as other) collection programs must include appropriate signage (minimal verbiage, pictures of accepted products) and be staffed at certain times, in order to minimize contamination problems. It may be of value to repeat this procedure on a regular basis for new participants or if material quality begins to deteriorate.
- Drop-off (as well as other) collection programs for multi-family residences must include continuous education of new tenants.
- Encourage and/or assist in the development of carefully designed educational literature to increase public understanding of which plastic products are currently recyclable. The literature should focus on specific types of product for recovery (milk, soft drink, laundry, plastic bags) and/or physical characteristics of the materials to be collected that are easily recognizable (e.g., narrow neck bottles). The literature should also stress the removal of caps, rinsing, and stepping the plastic bottles for volume reduction before collection.
- Develop educational literature on a technical operator's program to educate MRF and other plastic handling facility operators and ultimately their sorting line crew as to the appropriate plastics to be collected and methods for most effectively hand-sorting plastic [i.e., remove dominant resins first (PET soft drink, HDPE milk) followed by HDPE laundry (light/dark cut sort), clear bottles into PET and PVC, etc.)]
- Attempt to establish grinding operations at the handling facility in order to improve the MRF's or other plastic handling facility's net income stream from plastic. It will be extremely important to establish a close working relationship

with one or more plastic reclaimers willing to accept the ground material prior to implementation.

- Continue to monitor the commercialization of automated sorting technology. The advent of such technology will likely dictate the future course of residential postconsumer plastic bottle recovery efforts.

Section 4 CONCLUSIONS

1. The following are barriers to the use of recycled plastic in products with broad resin specifications.
 - There are a limited number of products with broad resin specifications.
 - Durable products, such as plastic lumber and recycling containers, will not provide a closed-loop end-use for plastic recovered from non-durables such as packaging.
 - Markets for many products with broad resin specifications, such as plastic lumber and flower pots, are limited.
2. Opportunities for recycled products with narrow resin specifications have been growing as improvements in the supply of PCR, technologies, and markets occur.
3. The following are barriers to the use of recycled plastic in products with narrow resin specifications:
 - Regulations regarding direct food containers,
 - Technical limits to recycled content,
 - Supply and quality of collected scrap,
 - Consumer perceptions of plastic recyclability,
 - Manufacturers concern about the use of recycled resins.

4. Manufacturers of products with very narrow resin specifications are not likely to incorporate PCR into their products for the following reasons:

- Many products use resins which are not found in large amounts in the residential waste stream, such as PP and PVC.
- PCR does not meet the resin specifications standards of these manufacturers and current technology is not capable of consistently bringing the quality of the PCR to these standards.

RECOMMENDATIONS

1. Because post-consumer resin ("PCR") will compete with both virgin resin and commercial/industrial scrap, the importance of developing a clean, well-sorted supply of PCR is critical to the success of recycling.

- NERC should encourage manufacturers to "design for recyclability" by urging the use of identical, or at least recycling-compatible, resins in product types.

2. NERC could encourage the purchase of recycled plastic products by individual consumers and government entities.

3. NERC should encourage performance-based standards for government procurement policies. The public will not be served by encouraging lower standards for recycled products.

For the long-term, recycled products should compete equally with products made with virgin resin. A graduated price preference for some products for two or three years may be advisable, but this should be phased out as soon as possible.

4. Minimum content legislation can be an effective tool in promoting the recycling of plastic.

- NERC can coordinate legislative initiatives within its membership, and beyond, so that the manufacturers of plastic

CONCLUSIONS AND RECOMMENDATIONS

products are not faced with multiple state standards for recycled content of products.

- A recycled content of 10 percent for plastic products with narrow resin specifications is reasonable and technically feasible, assuming a clear supply of PCR is available. An exception for products requiring Food and Drug Administration approval would have to be allowed. Percentages in excess of 10 percent are not technically feasible for many products at the present time.
 - NERC should be aware that the timing and structure of minimum content legislation is very important. Commodity prices, such as those for virgin resin, tend to be cyclical. The current low price of virgin resin is forcing the price of recycled resin down. Legislation providing price supports or other incentives may not be necessary when the price for virgin resin cycles upward.
5. Along with coordinating minimum content legislation, NERC could also promote and coordinate labeling standards, so that manufacturers and consumers would have a clear understanding of the recycled content of plastic packages and products.
6. Certain technical problems in recycling plastic, such as the degradation of plastic as it is recycled, must be solved by the industry. NERC may wish to encourage research and development by industry in areas such as:
- Sorting technologies
 - Application of technologies for upgrading or improving recycled resins to meet higher performance standards
 - Development of new products specifically designed for recycled plastics
 - Development of improved manufacturing processes for fabricating recycled resins into finished products
 - Commercialization of depolymerization technologies to increase the quality of PCR.

Section 5

7. Governments should provide incentives to manufacturers encouraging them to test market new products using high percentages of PCR.

APPENDIX A
FABRICATION TECHNOLOGIES

FABRICATION TECHNOLOGIES

Seven of the most common plastic fabrication technologies are summarized below. The purpose of these summaries is to introduce the reader to some of the ways in which plastic is shaped and molded in the manufacture of products.

This is not intended to be a comprehensive listing of all types of fabrication; nor is it intended to be a complete description of these technologies. For more information, see Modern Plastics Encyclopedia (McGraw-Hill, 1990).

Calendering - Calendering is a process in which plastic is run through a series of rolls to produce high-quality film and sheeting. It is used primarily with PVC, although PE, PP, and ABS can also be calendered. About 80 percent of the calendering lines produce PVC products.

Compression Molding - Compression molding is a simple process in which the plastic is placed in a heated cavity and put under pressure until it is cured. The simplicity of the process means minimal operating costs and little loss of material.

Extrusion - Extrusion involves the transformation of powder or pellets into a plastic melt, and the forcing of this melted plastic through a die to achieve the desired shape. After passing through the die, the melted plastic is cooled and hardened. The variety of extruded products include house siding, pipes, film, bottles, cups and plates.

Foam Processing - Foam is made from beads of resin, such as PS and PP, which contain a blowing agent which expands when exposed to heat. The rate of expansion can be controlled by controlling the heat in a steam chamber or mold.

Injection Molding - Injection molding is a process where plastic is melted and injected into a mold. The mold is then cooled and the plastic hardens to the shape of the mold. The product is then removed. Injection molded products include screws, pipe fittings, and toys.

Rotational Molding - In this process, powdered or liquid resin is placed in a closed mold which is attached to a rotator. The mold and rotator are enclosed in an oven. As the mold rotates, the resin is spread evenly over the surface of the mold. At the same time, heat is applied to fuse the resin and form an even coating. The rotator continues to operate as the coating is cooled. Large hollow products, such as kayaks and drums, are made using this process.

Blow-Molding - This process adds air to other fabrication processes to force plastic against the sides of a mold. The process is used to produce jars, bottles, drums, toys, and fuel tanks. Of the six resins under consideration, the most common ones used with blow-molding are HDPE, LDPE, PVC, and PET. There are three methods of blow-molding commonly in use.

Extrusion blow-molding combines extrusion and blow-molding technologies and is used for about 75 percent of all blow-molded products. This process involves extruding a plastic tube, closing a mold over the tube, and blowing the walls of the tube against the walls of the mold cavity. The blown part is then removed and trimmed.

As its name suggests, injection-blow molding combines injection molding and blow molding technologies. It is particularly useful for small bottles with screw-on tops which must be made to very close tolerances. A plastic preform is injected into a mold cavity around a core pin. In this cavity, it is heated and the neck of the bottle formed. The preform is then transferred to a blow mold where air is fed through the core pin and the bottle blown against the mold. Once this operation is finished, the bottle is then ejected from the mold.

Injection-stretch blow molding is a further refinement of injection-blow molding. In this process, the molecules of the bottle are stretched by heating the preform between the injection mold and the blow mold. This stretching aligns the molecules to give the bottle better impact and barrier properties and greater clarity.

APPENDIX B
1990 SALES OF PLASTIC RESINS

The following tables show the 1990 sales of seven plastic resins based on figures from Modern Plastics (January, 1991). The product types have been placed into one of three categories:

- (NDC) Non-Durable Consumer Products, such as packaging and disposables
- (D/C) Durable Consumer Products, such as toys and furniture
- (C/I) Commercial Industrial Products, such as construction materials and transportation applications

**NORTHEAST RECYCLING COUNCIL
PLASTIC MARKET ANALYSIS**

1990 SALES OF PLASTIC RESINS

POLYVINYL CHLORIDE		SPI CODE #3		
(All sales in millions of lbs, unless otherwise noted)				
1990 PLASTIC SALES:		61,480		
1990 PVC SALES:		9,297	15.12% of all plastic sales	
MAJOR PRODUCT CATEGORIES		1990 U.S. SALES	PERCENT OF TOTAL PVC RESIN SALES	PERCENT OF TOTAL PLASTIC SALES
CALENDERING				
BUILDING & CONSTRUCTION	(C/I)	348	3.74%	0.57%
TRANSPORTATION	(C/I)	90	0.97%	0.15%
PACKAGING	(NDC)	115	1.24%	0.19%
ELECTRICAL TAPES		13	0.14%	0.02%
CONSUMER & INSTITUTIONAL	(C/I)	287	3.09%	0.47%
FURNITURE/FURNISHINGS	(D/C)	200	2.15%	0.33%
TOTAL CALENDERING		1,053	11.33%	1.71%
EXTRUSION				
BUILDING AND CONSTRUCTION				
PIPE AND CONDUIT				
WATER	(C/I)	1,338	14.39%	2.18%
GAS	(C/I)	32	0.34%	0.05%
IRRIGATION	(C/I)	190	2.04%	0.31%
OTHER	(C/I)	65	0.70%	0.11%
DRAIN/WASTE/VENT	(C/I)	585	6.29%	0.95%
CONDUIT	(C/I)	585	6.29%	0.95%
SEWER/DRAIN	(C/I)	743	7.99%	1.21%
OTHER	(C/I)	72	0.77%	0.12%
SIDING & ACCESSORIES	(C/I)	860	9.25%	1.40%
WINDOWS	(C/I)	401	4.31%	0.65%
TRANSPORTATION	(C/I)	20	0.22%	0.03%
PACKAGING	(NDC)	365	3.93%	0.59%
ELECTRIC WIRE & CABLE	(C/I)	410	4.41%	0.67%
CONSUMER & INSTITUTIONAL	(C/I)	307	3.30%	0.50%
TOTAL EXTRUSION		5,973	64.25%	9.72%
INJECTION MOLDING				
BUILDING & CONSTRUCTION	(C/I)	182	1.96%	0.30%
TRANSPORTATION	(C/I)	10	0.11%	0.02%
ELECTRICAL/ELECTRONICS	(C/I)	135	1.45%	0.22%
CONSUMER & INSTITUTIONAL	(C/I)	73	0.79%	0.12%
OTHER	(C/I)	20	0.22%	0.03%

**NORTHEAST RECYCLING COUNCIL
PLASTIC MARKET ANALYSIS**

1990 SALES OF PLASTIC RESINS

POLYVINYL CHLORIDE		SPI CODE #3	
(All sales in millions of lbs, unless otherwise noted)			
1990 PLASTIC SALES:	61,480		
1990 PVC SALES:	9,297	15.12%	of all plastic sales
MAJOR PRODUCT CATEGORIES	1990 U.S. SALES	PERCENT OF TOTAL PVC RESIN SALES	PERCENT OF TOTAL PLASTIC SALES
TOTAL INJECTION MOLDING	420	4.52%	0.68%
BLOW-MOLDED BOTTLES (NDC)	223	2.40%	0.36%
COMPRESSION-MOLDED RECORDS (D/C)	20	0.22%	0.03%
DISPERSION MOLDING			
TRANSPORTATION (C/I)	40	0.43%	0.07%
PACKAGING CLOSURES (NDC)	40	0.43%	0.07%
CONSUMER & INSTITUTIONAL (C/I)	61	0.66%	0.10%
INDUSTRIAL - TRAFFIC CONES (C/I)	12	0.13%	0.02%
ADHESIVES (C/I)	59	0.63%	0.10%
OTHER (C/I)	13	0.14%	0.02%
TOTAL DISPERSION MOLDING	225	2.42%	0.37%
DISPERSION COATING			
BUILDING FLOORING (C/I)	165	1.77%	0.27%
TRANSPORTATION (C/I)	38	0.41%	0.06%
CONSUMER & INSTITUTIONAL (C/I)	61	0.66%	0.10%
FURNITURE/FURNISHINGS (DC)	92	0.99%	0.15%
OTHER (C/I)	25	0.27%	0.04%
TOTAL DISPERSION COATING	381	4.10%	0.62%
VINYL LATEXES (C/I)	65	0.70%	0.11%
EXPORT	937	10.08%	1.52%
GRAND TOTAL	9,297	100.00%	15.12%

**NORTHEAST RECYCLING COUNCIL
PLASTIC MARKET ANALYSIS**

1990 SALES OF PLASTIC RESINS

POLYPROPYLENE (PP)		SPI CODE #5		
(All sales in millions of lbs, unless otherwise noted)				
1990 PLASTIC SALES:		61,480		
1990 PP SALES:		8,132	13.23% of all plastic sales	
MAJOR PRODUCT CATEGORIES		1990 U.S. SALES	PERCENT OF TOTAL PP RESIN SALES	PERCENT OF TOTAL PLASTIC SALES
BLOW MOLDING				
MEDICAL CONTAINERS	(C/I)	55	0.68%	0.09%
CONSUMER PACKAGING	(NDC)	93	1.14%	0.15%
TOTAL BLOW MOLDING		148	1.82%	0.24%
EXTRUSION				
COATING	(C/I)	35	0.43%	0.06%
FIBERS AND FILAMENTS	(C/I)	2,130	26.19%	3.46%
FILM (10 mil-)	(C/I)	588	7.23%	0.96%
PIPE AND CONDUIT	(C/I)	32	0.39%	0.05%
SHEET (10 mil+)	(C/I)	138	1.70%	0.22%
STRAWS	(NDC)	56	0.69%	0.09%
WIRE AND CABLE	(C/I)	47	0.58%	0.08%
OTHER	(C/I)	8	0.10%	0.01%
TOTAL EXTRUSION		3,034	37.31%	4.93%
INJECTION MOLDING				
APPLIANCES				
MAJOR	(DC)	126	1.55%	0.20%
SMALL	(DC)	59	0.73%	0.10%
FURNITURE	(DC)	105	1.29%	0.17%
HOUSEWARES	(NDC)	272	3.34%	0.44%
LUGGAGE & CASES	(DC)	12	0.15%	0.02%
MEDICAL	(C/I)	168	2.07%	0.27%
PACKAGING				
CLOSURES	(NDC)	412	5.07%	0.67%
CONTAINERS	(NDC)	202	2.48%	0.33%
TOYS AND NOVELTIES	(NDC)	48	0.59%	0.08%
TRANSPORTATION				
BATTERY CASES	(DC)	96	1.18%	0.16%
OTHER	(C/I)	250	3.07%	0.41%
OTHER	(C/I)	190	2.34%	0.31%
TOTAL INJECTION MOLDING		1,940	23.86%	3.16%
EXPORTS		1,540	18.94%	2.50%
OTHER	(C/I)	1,470	18.08%	2.39%
GRAND TOTAL		8,132	100.00%	13.23%

**NORTHEAST RECYCLING COUNCIL
PLASTIC MARKET ANALYSIS**

1990 SALES OF PLASTIC RESINS

HIGH DENSITY POLYETHYLENE (HDPE) SPI CODE #2

(All sales in millions of lbs, unless otherwise noted)

1990 PLASTIC SALES:

61,480

1990 HDPE SALES:

8,505

13.83% of all plastic sales

MAJOR PRODUCT CATEGORIES		1990 U.S. SALES	PERCENT OF TOTAL HDPE RESIN SALES	PERCENT OF TOTAL PLASTIC SALES
BLOW MOLDING				
BOTTLES				
MILK	(NDC)	736	8.65%	1.20%
HOUSEHOLD CHEMICALS	(NDC)	926	10.89%	1.51%
PHARMACEUT., COSMETICS	(NDC)	202	2.38%	0.33%
OTHER FOOD	(NDC)	340	4.00%	0.55%
DRUMS	(C/I)	134	1.58%	0.22%
FUEL TANKS	(C/I)	103	1.21%	0.17%
TIGHT-HEAD PAILS	(C/I)	80	0.94%	0.13%
TOYS	(NDC)	72	0.85%	0.12%
HOUSEWARES	(NDC)	53	0.62%	0.09%
OTHER	(C/I)	264	3.10%	0.43%
TOTAL BLOW MOLDING		2,910	34.22%	4.73%
EXTRUSION				
COATING	(C/I)	53	0.62%	0.09%
MERCHANDISE BAGS	(NDC)	206	2.42%	0.34%
T-SHIRT SACKS	(NDC)	255	3.00%	0.41%
TRASH BAGS				
INSTITUTIONAL	(C/I)	147	1.73%	0.24%
CONSUMER	(NDC)	21	0.25%	0.03%
FOOD PACKAGING	(NDC)	131	1.54%	0.21%
DELI PAPER	(NDC)	18	0.21%	0.03%
MULTI-WALL SACK LINERS	(C/I)	56	0.66%	0.09%
OTHER	(C/I)	85	1.00%	0.14%
PIPE				
CORRUGATED	(C/I)	114	1.34%	0.19%
WATER	(C/I)	67	0.79%	0.11%
OIL & GAS PRODUCTION	(C/I)	77	0.91%	0.13%
INDUSTRIAL/MINING	(C/I)	70	0.82%	0.11%
GAS	(C/I)	130	1.53%	0.21%
IRRIGATION	(C/I)	44	0.52%	0.07%
OTHER	(C/I)	45	0.53%	0.07%
SHEET (12 mil+)	(C/I)	332	3.90%	0.54%
WIRE & CABLE	(C/I)	164	1.93%	0.27%

**NORTHEAST RECYCLING COUNCIL
PLASTIC MARKET ANALYSIS**

1990 SALES OF PLASTIC RESINS

HIGH DENSITY POLYETHYLENE (HDPE) SPI CODE #2			
(All sales in millions of lbs, unless otherwise noted)			
1990 PLASTIC SALES:	61,480		
1990 HDPE SALES:	8,505	13.83%	of all plastic sales
MAJOR PRODUCT CATEGORIES	1990 U.S. SALES	PERCENT OF TOTAL HDPE RESIN SALES	PERCENT OF TOTAL PLASTIC SALES
OTHER EXTRUSION (C/I)	39	0.46%	0.06%
TOTAL EXTRUSION	2,054	24.15%	3.34%
INJECTION MOLDING			
INDUSTRIAL CONTAINERS			
DAIRY CRATES (C/I)	67	0.79%	0.11%
CRATES, CASES, PALLETS (C/I)	136	1.60%	0.22%
PAIS (C/I)	414	4.87%	0.67%
CONSUMER PACKAGING			
MILK BOTTLE CAPS (NDC)	26	0.31%	0.04%
OTHER CAPS (NDC)	58	0.68%	0.09%
DAIRY TUBS (NDC)	155	1.82%	0.25%
ICE CREAM CONTAINERS (NDC)	96	1.13%	0.16%
OTHER FOOD CONTAINERS (NDC)	55	0.65%	0.09%
BEVERAGE BOTTLE BASES (NDC)	125	1.47%	
PAINT CANS (NDC)	33	0.39%	0.05%
HOUSEWARES (NDC)	180	2.12%	0.29%
TOYS (NDC)	82	0.96%	0.13%
OTHER INJECTION (C/I)	153	1.80%	0.25%
TOTAL INJECTION MOLDING	1,580	18.58%	2.57%
ROTOMOLDING (C/I)	75	0.88%	0.12%
EXPORT	712	8.37%	1.16%
OTHER (C/I)	1,174	13.80%	1.91%
GRAND TOTAL	8,505	100.00%	13.83%

**NORTHEAST RECYCLING COUNCIL
PLASTIC MARKET ANALYSIS**

1990 SALES OF PLASTIC RESINS

LOW DENSITY POLYETHYLENE (LDPE) SPI CODE #4				
(All sales in millions of lbs, unless otherwise noted)				
1990 PLASTIC SALES:		61,480		
1990 LDPE SALES:		6,170	10.14%	of all plastic sales
MAJOR PRODUCT CATEGORIES		1990 U.S. SALES	PERCENT OF TOTAL LDPE RESIN SALES	PERCENT OF TOTAL PLASTIC SALES
BLOW MOLDING	(NDC)	62	1.00%	0.10%
EXTRUSION				
COATING	(C/I)	725	11.75%	1.18%
FILM				
PACKAGING	(NDC)	1,827	29.61%	2.97%
NON-PACKAGING	(C/I)	1,165	18.88%	1.89%
PIPE	(C/I)	87	1.41%	0.14%
SHEET	(C/I)	64	1.04%	0.10%
WIRE & CABLE	(C/I)	177	2.87%	0.29%
OTHER	(C/I)	546	8.85%	0.89%
TOTAL EXTRUSION		4,591	74.41%	7.47%
INJECTION MOLDING	(C/I)	296	4.80%	0.98%
ROTOMOLDING	(C/I)	196	3.18%	0.32%
EXPORT		720	11.67%	1.17%
OTHER	(C/I)	367	5.95%	0.60%
GRAND TOTAL		6,170	100.00%	10.14%

**NORTHEAST RECYCLING COUNCIL
PLASTIC MARKET ANALYSIS**

1990 SALES OF PLASTIC RESINS

LINEAR LOW DENSITY POLYETHYLENE (LLDPE) (All sales in millions of lbs, unless otherwise noted)			
1990 PLASTIC SALES:	61,480		
1990 LLDPE SALES:	4,658	7.58%	of all plastic sales
MAJOR PRODUCT CATEGORIES	1990 U.S. SALES	PERCENT OF TOTAL LLDPE RESIN SALES	PERCENT OF TOTAL PLASTIC SALES
BLOW MOLDING (NDC)	28	0.60%	0.05%
EXTRUSION			
COATING (C/I)	9	0.19%	0.01%
FILM			
PACKAGING (NDC)	1,236	26.53%	2.01%
NON-PACKAGING (C/I)	1,610	34.56%	2.62%
PIPE (C/I)	65	1.40%	0.11%
SHEET (C/I)	18	0.39%	0.03%
WIRE & CABLE (C/I)	173	3.71%	0.28%
OTHER (C/I)	16	0.34%	0.03%
TOTAL EXTRUSION	3,127	67.13%	5.09%
INJECTION MOLDING (NDC)	537	11.53%	0.87%
ROTOMOLDING (C/I)	124	2.66%	0.20%
EXPORT	255	5.47%	0.41%
OTHER (C/I)	587	12.60%	0.95%
GRAND TOTAL	4,658	100.00%	7.58%

**NORTHEAST RECYCLING COUNCIL
PLASTIC MARKET ANALYSIS**

1990 SALES OF PLASTIC RESINS

POLYSTYRENE (PS)		SPI CODE #6		
(All sales in millions of lbs, unless otherwise noted)				
1990 PLASTIC SALES:		61,480		
1990 PS SALES:		5,137	8.36% of all plastic sales	
MAJOR PRODUCT CATEGORIES		1990 U.S. SALES	PERCENT OF TOTAL PS RESIN SALES	PERCENT OF TOTAL PLASTIC SALES
MOLDING (SOLID PS ONLY)				
CONSUMER ELECTRONICS	(DC)	590	11.49%	0.94%
FURNITURE & FURNISHINGS	(DC)	67	1.30%	0.11%
TOYS & RECREATIONAL	(NDC)	259	5.04%	0.42%
HOUSEWARES	(NDC)	190	3.70%	0.31%
BUILDING & CONSTRUCTION	(C/I)	59	1.15%	0.10%
MISCELLANEOUS CONSUMER	(C/I)	121	2.36%	0.20%
PACKAGING & DISPOSABLES	(NDC)	463	9.01%	0.75%
OTHER	(C/I)	130	2.53%	0.21%
TOTAL MOLDING		1,879	36.58%	3.06%
EXTRUSION (SOLID PS ONLY)				
CONSUMER ELECTRONICS	(DC)	123	2.39%	0.20%
FURNITURE/FURNISHINGS	(DC)	25	0.49%	0.04%
TOYS AND RECREATIONAL	(NDC)	35	0.68%	0.06%
HOUSEWARES	(NDC)	58	1.13%	0.09%
BUILDING & CONSTRUCTION	(C/I)	54	1.05%	0.09%
MISC. CONSUMER/INDUSTRIAL	(C/I)	80	1.56%	0.13%
PACKAGING & DISPOSABLES	(NDC)	810	15.77%	1.32%
OTHER	(C/I)	230	4.48%	0.37%
TOTAL EXTRUSION		1,415	27.55%	2.30%
EXTRUSION (FOAM)				
BOARD	(C/I)	150	2.92%	0.24%
SHEET	(C/I)	556	10.82%	0.90%
OTHER	(C/I)	31	0.60%	0.05%
TOTAL EXTRUSION (FOAM)		737	14.35%	1.20%
EXPANDABLE BEAD (EPS)			0.00%	0.00%
BUILDING & CONSTRUCTION	(C/I)	232	4.52%	0.38%
OTHER	(C/I)	44	0.86%	0.07%
PACKAGING	(NDC)	155	3.02%	0.25%
CUPS AND CONTAINERS	(NDC)	153	2.98%	0.25%
LOOSE FILL	(NDC)	75	1.46%	0.12%
TOTAL EXPANDABLE BEAD		659	12.83%	1.07%
EXPORT		196	3.82%	0.32%
OTHER	(C/I)	251	4.89%	0.41%
GRAND TOTAL		5,137	100.00%	8.36%

**NORTHEAST RECYCLING COUNCIL
PLASTIC MARKET ANALYSIS**

1990 SALES OF PLASTIC RESINS

POLYETHYLENE TEREPHTHALATE (PET) SPI CODE #1

(All sales in millions of lbs, unless otherwise noted)

1990 PLASTIC SALES: 61,480

1990 PET SALES: 2,139

3.48% of all plastic sales

MAJOR PRODUCT CATEGORIES		1990 U.S. SALES	PERCENT OF TOTAL PET RESIN SALES	PERCENT OF TOTAL PLASTIC SALES
BLOW MOLDING				
SOFT DRINK	(NDC)	754	35.25%	1.23%
CUSTOM BOTTLES	(NDC)	335	15.66%	0.54%
EXTRUSION				
FILM	(NDC)	545	25.48%	0.89%
MAGNETIC RECORDING FILM	(C/I)	85	3.97%	0.14%
OVENABLE TRAYS	(NDC)	45	2.10%	0.07%
TOTAL EXTRUSION		675	31.56%	1.10%
COATING - OVENABLE BOARD	(C/I)	11	0.51%	0.02%
SHEETING (BLISTERS, ETC.)	(NDC)	80	3.74%	0.13%
STRAPPING	(C/I)	34	1.59%	0.06%
EXPORTS		250	11.69%	0.41%
GRAND TOTAL		2,139	100.00%	3.48%

APPENDIX C
CHANGE IN MARKET SHARE FOR PLASTIC PRODUCTS

CHANGE IN MARKET SHARE FOR PLASTIC PRODUCTS

Introduction

As a material used in the manufacture of products and packaging, plastic has become increasingly plentiful in the stream of commerce and the Nation's waste stream. According to the United States Environmental Protection Agency's ("EPA") *"Characterization of Municipal Solid Waste in the United States", 1990 Update*, plastic has been the fastest growing material in the waste stream for the past three decades. In 1960, plastic was estimated to be 0.5 percent of the waste stream by weight; in 1988, that estimate was 8.0 percent, a 16-fold increase. This increase contrasts with metal, which decreased from 12 percent of the waste stream in 1960 to 8.5 percent of the waste stream in 1988, and glass, which went from 7.6 percent in 1960 to 8.5 percent of the waste stream in 1988, and is estimated to increase to more than 10 percent by the year 2010. Because plastic is such a light material, these percentages understate the true impact plastic products have on the waste stream. In terms of volume of material, plastic is currently estimated to comprise be more than 20 percent of the waste stream.

Plastics have become more plentiful in the waste stream as a result of two related phenomena. First, the use of plastics has grown through new products which have created whole new markets. From large, lightweight toys for children to synthetic textiles, there has been a steady stream of new plastic products. The second way in which plastics have grown is by replacing products which were traditionally made of other materials. The use of plastic for automobile parts, for instance, is quite common, replacing more traditional materials such as rubber and metal. Although market share can be considered a zero-sum game, with one product's gain being made at the expense of another product's loss, often a new product can expand the entire market.

In broad terms, the volume of plastic products has grown because plastic has proven to have technical advantages over other materials, favorable product economics, or a marketing edge.

Plastic has many technical advantages over other materials. In packaging, plastic film is lightweight, clear, strong, and creates an effective barrier against odor, bacteria, and moisture. The barrier reduces spoilage, a critical concern to food packages. This combination of qualities makes plastic film superior to alternatives such as paper or glass. For children's toys, plastic can be made non-toxic, brightly colored, strong, and light, making it more popular than wood or metal.

Plastic has economic advantages over other materials because it can be made into products which are inexpensive to manufacture and distribute. Because plastic can be mechanically molded into an infinite variety of finished shapes, it often has a clear economic advantage over wood or metal, which may require expensive hand-finishing.

Plastic's weight advantage over other materials makes it easier to handle and less expensive to transport. Plastic soft-drink containers have taken market share from glass because less of the shipping cost is spent shipping the containers and more can be spent shipping the soft drink. For example, a 16 ounce, non-refillable glass bottle weighs almost nine times more than a PET bottle, which holds the same amount of fluid.

For example, Table C-1 shows the comparative weight of some comparable containers of different materials.

Table C-1

Comparison of Soft-Drink Containers

Container	Weight	Grams/Oz. of Fluid
16 oz. PET Bottle	29 gms	1.81
16 oz. Non-Refillable Glass	206 gms	12.88
16 oz. Refillable Glass	399 gms	24.94
12 oz. Aluminum Can	17 gms	1.42
2 Liter (67.5 oz.) PET Bottle	71 gms	1.05

Both the PET bottle and the aluminum can are lighter weight than the glass bottle. The PET bottle is lighter, on a per unit basis, than aluminum only in the 2 Liter bottle.

Plastic's ability to be shaped and colored inexpensively gives it a distinct advantage in many packaging applications. Imaginative packages such as the L'eggs pantyhose "egg", has actually created demand for the product inside.

As the following examples show, the growth, or shrinkage, of plastic products or packages in the marketplace will affect its availability for recovery. The non-returnable High-Density Polyethylene ("HDPE") milk jug was introduced commercially in 1964 as an alternative to the glass milk bottle and the waxed cardboard milk carton. During the past five years, the HDPE milk jug has become the dominant container for milk with approximately 70 percent of the overall market share. Its dominance in the milk container market and the rapid growth of municipal recycling programs led it to be targeted for collection. Currently, approximately 3,340 municipal recycling programs are collecting HDPE milk jugs.

However, the position of HDPE jugs in the milk container market is not completely secure. General Electric has begun to test market a polycarbonate milk bottle, which has many of the same qualities as the HDPE milk jug, as well as several advantages. First, it can be refilled between 30 and 40 times. Second, it does not impart any flavor to the milk, so the milk tastes better. Third, the polycarbonate milk bottle is clear rather than cloudy; the consumer can thus see the actual color and quality of the milk. The polycarbonate milk bottle's capacity to displace the HDPE milk jug in the market place will obviously determine the amount of HDPE available for recycling.

In the second example, a new product was created, opening a whole new market for plastic. In 1971, L'eggs Products, Inc., introduced an injection molded polystyrene package shaped like an egg in which it sold its line of pantyhose. Up to that time, most pantyhose were sold in plastic pouches or in paper envelopes with a plastic window. The package, clever and attractive, helped make L'eggs pantyhose the most popular brand on the market ever since its introduction, according to company officials. It currently holds a 55 percent share of the food, drug, and discount store market.

Over the past 20 years, however, the novelty of the package has apparently worn off. In July of 1991, the company announced that it would discontinue the plastic egg package and replace it with a recycled paperboard carton. Company officials stated that they had instituted the change because, after 20 years with the same packaging, their product needed an image update. They also indicated, though, that the switch would help L'eggs Products, Inc., realize its waste reduction goals by employing just one paperboard carton rather than two pieces of plastic shell, a paperboard base, and a paperboard product information card. Company officials also offered improved package handling, easier-to-read product information, and more environmental benefits as reasons for the packaging change.

The third example involves the most dramatic shift in market share of a plastic product in recent memory. In November of 1990, the McDonald's Corporation announced that it would stop using polystyrene foam "clamshells" in favor of coated paper wrappers in its 8,000 United States restaurants. Prior to this change, it was estimated that McDonald's had been using about 8 percent of the one billion pounds of foam packaging produced annually in the United States. The packaging that will be affected by this change represents approximately 75 percent of McDonald's Corporation's polystyrene use.

McDonald's decision was influenced, in part, by the public belief that plastic is environmentally harmful. This belief has led communities such as Portland, Oregon and Suffolk County, New York to ban the use of polystyrene. However, in its announcement of the change, McDonald's said the switch to coated paper wrappers was designed to significantly reduce the volume of waste which McDonald's disposes. It should be noted that the coated paper wrappers are not currently recyclable because they contain a combination of paper and plastic.

This shift from plastic to paper is apt to affect more than just the 60 million pounds of polystyrene available for collection from McDonald's. It could also influence other fast food restaurants and food service organizations to follow suit. The result could be a ripple effect, which would reduce the amount of polystyrene in the waste stream even further.

Conclusion

Shifts in market share of certain plastic products have certainly affected the availability of resins/products for collection, as these examples suggest. The introduction of the HDPE milk jug created a stream of material available for recovery. McDonald's decision to drop three-quarters of its polystyrene foam packaging will certainly decrease the availability of this product for recovery.

Because of its many technical and economic advantages over other materials, the growth of plastics has been rapid and sustained. It is unlikely that new technologies, shifts in consumer taste, or corporate or legislative mandates against specific plastic products, such as McDonald's decision to replace polystyrene "clamshells", will eliminate the need to recover plastics.

APPENDIX D
MANUFACTURERS OF RECYCLED PLASTIC
PRODUCTS IN THE NORTHEAST

MANUFACTURERES OF RECYCLED PLASTIC PRODUCTS IN THE NORTHEAST

The following list of manufacturers was developed on the basis of discussions with state agencies, published information, and conversations with industry sources. According to the 1987 Census of Manufacturers, there are more than 2,800 firms producing plastic products in the northeast. The number of these firms using PCR is likely to change over time given the state of the economy and the rapid changes in technology, market demand, and legislation.

Manufacturers of Recycled Products with Broad Resin Specifications:

Plastic Lumber and Lumber Products

National Waste Technologies
934 Easton Street
Ronkonkoma, New York 11779
(516) 588-4545

Plastic Recyclers
75 Wyandanch Avenue
Wyandanch, New York 11789
(516) 491-1490

Recycled Plastic Products
Gary Plastic Packaging Corporation
770 Garrison Avenue
Bronx, New York 10474
(212) 893-2220

Rivinite
6801 State Road
Building B
Philadelphia, Pennsylvania 19135
(215) 333-6615

EviroSAFE
P.O. Box 1074
Murray Hill Station
New York, New York 10156
(212) 529-3720

Trimax, Inc.
20776 Fifth Avenue
Ronkonkoma, New York 11779
(516) 471-7777

Mid-Atlantic Plastic Systems
320 Chestnut Street
Roselle, New Jersey 07203
(908) 241-9333

Obex, Inc.
P.O. Box 1253
Stamford, Connecticut 06904-1253
(203) 975-9094

Polyforms
235 Main Street
Ridgeway, Pennsylvania 15853
(814) 772-1745

Recycled Containers

Plastican
196 Industrial Blvd.
Leominster, Massachusetts 01453
(508) 537-4911

Tulip Corporation
3125 Highland Avenue
Niagara Falls, New Jersey 14305
(716) 282-1261

Piper CasePro, Inc.
2517 Highway 35
Suite 101 N
Manasquan, New Jersey 08736
(210) 223-0623

Manufacturers of Recycled Products with Narrow Resin Specifications:

Geotextile Landfill Liners

JPS Elastomerics Corporation
395 Pleasant Street
Northampton, Massachusetts 01060
(413) 586-8750

Film Bags

Webster Industries
58 Pulaski Street
Peabody, Massachusetts 01960
(508) 532-2000 ext. 140

Building Supplies

Laminations/PolyCycle, Inc.
P.O. Box 2021
Scranton, Pennsylvania 18501
(717) 343-7921

Toys

Come Play Products
44 Suffolk Street
Worcester, Massachusetts 01604
(508) 756-8353

Repolymerized Bottles

Hoechst Celanese Corporation
26 Main Street
Chatham, New Jersey 07928
(201) 635-2600

Eastman Chemical
5700 Tacony Street
Rochester, New York 19135
(716) 325-5030

Office Products

Acme United Corporation
70 Kingshighway Cut-Off
Fairfield, Connecticut 06430
(203) 332-7330

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Center for Plastics Recycling Research
Rutgers University
Piscataway, NJ

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Minneapolis"
Council for Solid Waste Solutions
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Environmental Defense Fund/McDonald's Corporation
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by R. W. Beck and Associates

"1990 Postconsumer Plastics Recycling Rate Study"
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Plastics Recycling Foundation
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Illinois Department of Energy and Natural Resources

November, 1990

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